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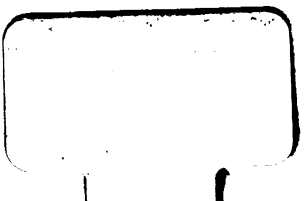

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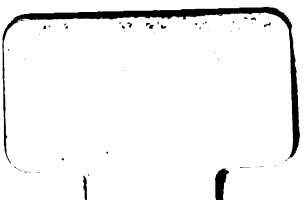

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# WIRE

IN

# Electrical Construction

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JOHN A. ROEBLING'S SONS CO.

TRENTON, N. J.

117–119 Liberty street,
NEW YORK.

171–173 Lake street,
CHICAGO.

32 South Water street,
CLEVELAND.

25–27 Fremont street,
SAN FRANCISCO.

The Brandt Press,
Trenton.
1897.


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# PREFATORY.

THE OBJECT of this book is to give in a convenient form the properties and dimensions of bare and insulated wires and cables used in electrical construction. No attempt has been made to describe the uses of wire in any of the applications of electricity. To go into this would require that the whole field of electrical engineering be covered.

It is believed that some of the matter is new. All of the tables have been very carefully computed, and are believed to be correct.

In nearly all cases the formulæ and constants used in computing tables are given, so that the user can determine at once the basis from which the table was calculated. A considerable amount of work has been done in testing samples to determine the proper constants. In many cases this has taken more time than the actual preparation of the tables.

It is hoped that the work will be acceptable to the users of electrical wires, and that some of the labor involved in the preparation of these tables will be saved to those using the book.

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TRENTON, N. J., May, 1897.



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## MEASURES OF LENGTH.

| Names of units. | Inches. | Feet. | Yards. | Meters. | Chains. | Kilometers. | Miles. | Knots. |
|---|---|---|---|---|---|---|---|---|
| Inches | 1. | .083 33 | .027 78 | .025 4 | .001 26 | .000 025 | .000 015 8 | .000 013 7 |
| Feet | 12. | 1. | .333 33 | *.304 801 | .015 15 | .000 305 | .000 189 | .000 164 5 |
| Yards | 36. | 3. | 1. | *.914 402 | .045 45 | .000 914 | .000 568 | .000 493 4 |
| Meters | *39.37 | *3.280 83 | *1.093 611 | 1. | .049 71 | .001 | .000 621 | .000 54 |
| Chains | 792. | 66. | 22. | 20.116 9 | 1. | .020 116 9 | .012 5 | .010 855 |
| Kilometers | 39 370. | 3 280.83 | 1 093.61 | 1 000. | 49.71 | 1. | *.621 37 | .539 61 |
| Miles | 63 360. | 5 280. | 1 760. | 1 609.35 | 80. | *1.609 35 | 1. | .868 42 |
| Knots | 72 960. | 6 080. | 2 026.66 | 1 853.19 | 92.112 | 1.853 19 | 1.151 5 | 1. |

Mil = .001 inch.

In these tables the equivalents of the metric system of weights and measures are those given in 1890 by the United States Coast and Geodetic Survey, Office of Standard Weights and Measures. These values in all the tables are marked by an asterisk (*). The other equivalents are calculated from these.

In the metric system the following prefixes are used for subdivisions and multiples:

| | |
|---|---|
| Milli = $\frac{1}{1000}$ | Deca = 10 |
| Centi = $\frac{1}{100}$ | Hecto = 100 |
| Deci = $\frac{1}{10}$ | Kilo = 1 000 |
| | Myria = 10 000 |

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## MEASURES OF AREA.

| Names of units. | Circular mils. | Square mils. | Square millimeters. | Square centimeters. | Square inches. | Square feet. | Square yards. | Square meters. |
|---|---|---|---|---|---|---|---|---|
| Circular mils | 1. | .785 4 | .000 506 7 | ..... .. | ..... | ..... | ..... | ..... |
| Square mils | 1.273 2 | 1. | .000 645 | .000 006 4 | .000 001 | ..... ..... | ..... | ..... |
| Square millimeters | 1 973.5 | 1 550.1 | 1. | .01 | .001 55 | ..... | ..... | ..... |
| Square centimeters | 197 350. | 155 010. | 100. | 1. | *.155 | .001 077 | .000 12 | .000 1 |
| Square inches | 1 273 239. | 1 000 000. | 645.2 | *6.452 | 1. | .006 94 | .000 77 | .000 645 |
| Square feet | ..... | ..... | 92 900. | 929. | 144. | 1. | .111 11 | .092 9 |
| Square yards | ..... ..... | ..... | 836 100. | 8 361. | 1 296. | 9. | 1. | *.836 |
| Square meters | ..... | ..... | 1 000 000. | 10 000. | 1 550.016 | *10.764 | *1.196 | 1. |

Circular mil = a circle whose diameter is .001 inch.
Square mil = a square whose sides are .001 inch.

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## MEASURES OF VOLUME.

| Names of units. | Cubic centimeters. | Cubic inches. | Liters. | Gallons. | Cubic feet. | Cubic yards. | Cubic meters. |
|---|---|---|---|---|---|---|---|
| Cubic centimeters | 1. | *.061 | .001 | .000 264 | .000 035 | .000 001 3 | .000 001 |
| Cubic inches | *16.387 | 1. | .016 387 | .004 33 | .000 578 | .000 021 4 | .000 016 |
| Liters | 1 000. | 61.023 | 1. | *.264 17 | .035 314 | .001 308 | .001 |
| Gallons | 3 785.4 | 231. | *3.785 44 | 1. | .133 68 | .004 952 | .003 785 |
| Cubic feet | 28 315. | 1 728. | 28.315 | 7.48 | 1. | .037 037 | *.028 32 |
| Cubic yards | 764 552. | 46 656. | 764.55 | 201.97 | 27. | 1. | *.765 |
| Cubic meters | 1 000 000. | 61 023. | 1 000. | 264.17 | *35.314 | *1.308 | 1. |

Fluid ounce = 29.57 cubic centimeters.
Gallon = 128 fluid ounces.

Gallon = 4 quarts.
Quart = 2 pints.



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## MEASURES OF WEIGHT.

| Names of units. | Grains. | Grams. | Ounces avoirdupois. | Pounds troy. | Pounds avoirdupois. | Kilograms. |
|---|---|---|---|---|---|---|
| Grains | 1. | .064 798 9 | .002 28 | .000 174 | .000 143 | .000 064 |
| Grams | *15.432 | 1. | .035 27 | .002 68 | .002 205 | .001 |
| Ounces avoirdupois | 437.5 | *28.349 5 | 1. | .075 95 | .062 5 | .028 35 |
| Pounds troy | 5 760. | 373.24 | 13.166 | 1. | .822 86 | .373 24 |
| Pounds avoirdupois | 7 000. | 453.59 | 16. | 1.215 3 | 1. | *.453 59 |
| Kilograms | *15 432.36 | 1 000. | 35.274 | 2.679 2 | *2.204 62 | 1. |
| Long tons | 15 680 000. | 1 016 041.6 | 35 840. | 2 722.2 | 2 240. | 1 016.04 |

1 kilogram per kilometer = .671 95 pounds per 1 000 feet.
1 pound per thousand feet = 1.488 2 kilograms per kilometer.

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## MEASURES OF WORK.

| Names of units. | Ergs. | Gram-degree Centigrade. | Pound-degree Fahrenheit. | Watt-second. | Kilogram-meter. | Foot-pound. | Horse-power-second. |
|---|---|---|---|---|---|---|---|
| Gram-degree Centigrade..... | 41 549 500. | 1. | .003 968 3 | 4.154 95 | .423 54 | 3.063 5 | .005 57 |
| Pound-degree Fahrenheit..... | 10 470 300 000. | 252.11 | 1. | 1 047.03 | 106.731 | 772. | 1.403 |
| Watt-second..... | 10 000 000. | .240 7 | .000 955 1 | 1. | .101 937 | .737 324 | .001 340 6 |
| Kilogram-meter . ..... | 98 100 000. | 2.361 | .009 369 | 9.81 | 1. | 7.233 14 | .013 151 |
| Foot-pound..... | 13 562 600. | .326 4 | .001 295 3 | 1.356 26 | .138 25 | 1. | .001 818 18 |
| Horse-power-second ..... | ..... | 179.5 | .712 4 | 745.94 | 76.039 | 550. | 1. |

Joule = volt-coulomb = watt for one second.

Calorie = gram-degree Centigrade.

B. T. U. = British thermal unit = pound-degree Fahrenheit.



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## MEASURES OF PRESSURE.

| Names of units. | Atmospheres. | Pounds on square inch. | Inches of mercury at 32° F. | Feet of water at 60° F. | Millimeters of mercury at 32° F. | Pounds on square foot. | Kilograms on square meter. |
|---|---|---|---|---|---|---|---|
| Atmospheres | 1. | 14.7 | 29.922 | 33.94 | 760. | 2 116. | 10 333. |
| Pounds on square inch | .068 03 | 1. | 2.036 | 2.309 | 51.7 | 143.946 | 702.925 |
| Inches of mercury at 32° F | .033 42 | .491 3 | 1. | 1.134 | 25.398 | 70.7 | 345.331 |
| Feet of water at 60° F | .029 47 | .433 2 | .881 8 | 1. | 22.399 | 62.35 | 304.565 |
| Millimeters of mercury at 32° F | .001 316 | .019 34 | .039 37 | .044 64 | 1 | 2.784 | 13.596 |
| Pounds on square foot | .000 472 6 | .006 947 | .014 14 | .016 03 | .359 2 | 1. | 4.883 |
| Kilograms on square meter | .000 096 77 | .001 423 | .002 895 | .003 283 | .073 55 | .204 8 | 1. |

1 kilogram per square millimeter = 1423 pounds per square inch.
1 pound per square inch = .000 703 kilograms per square millimeter.

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## DECIMAL EQUIVALENTS OF PARTS OF AN INCH.

| 16ths. | 32ds. | 64ths. | Mils. | 16ths. | 32ds. | 64ths. | Mils. |
|---|---|---|---|---|---|---|---|
| | | 1 | 15.625 | | | 33 | 515.625 |
| | 1 | 2 | 31.25 | | 17 | 34 | 531.25 |
| | | 3 | 46.875 | | | 35 | 546.875 |
| 1 | 2 | 4 | 62.5 | 9 | 18 | 36 | 562.5 |
| | | 5 | 78.125 | | | 37 | 578.125 |
| | 3 | 6 | 93.75 | | 19 | 38 | 593.75 |
| | | 7 | 109.375 | | | 39 | 609.375 |
| 2 | 4 | 8 | 125. | 10 | 20 | 40 | 625. |
| | | 9 | 140.625 | | | 41 | 640.625 |
| | 5 | 10 | 156.25 | | 21 | 42 | 656.25 |
| | | 11 | 171.875 | | | 43 | 671.875 |
| 3 | 6 | 12 | 187.5 | 11 | 22 | 44 | 687.5 |
| | | 13 | 203.125 | | | 45 | 703.125 |
| | 7 | 14 | 218.75 | | 23 | 46 | 718.75 |
| | | 15 | 234.375 | | | 47 | 734.375 |
| 4 | 8 | 16 | 250. | 12 | 24 | 48 | 750. |
| | | 17 | 265.625 | | | 49 | 765.625 |
| | 9 | 18 | 281.25 | | 25 | 50 | 781.25 |
| | | 19 | 296.875 | | | 51 | 796.875 |
| 5 | 10 | 20 | 312.5 | 13 | 26 | 52 | 812.5 |
| | | 21 | 328.125 | | | 53 | 828.125 |
| | 11 | 22 | 343.75 | | 27 | 54 | 843.75 |
| | | 23 | 359.375 | | | 55 | 859.375 |
| 6 | 12 | 24 | 375. | 14 | 28 | 56 | 875. |
| | | 25 | 390.625 | | | 57 | 890.625 |
| | 13 | 26 | 406.25 | | 29 | 58 | 906.25 |
| | | 27 | 421.875 | | | 59 | 921.875 |
| 7 | 14 | 28 | 437.5 | 15 | 30 | 60 | 937.5 |
| | | 29 | 453.125 | | | 61 | 953.125 |
| | 15 | 30 | 468.75 | | 31 | 62 | 968.75 |
| | | 31 | 484.375 | | | 63 | 984.375 |
| 8 | 16 | 32 | 500. | 16 | 32 | 64 | 1 000. |

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## WIRE GAUGES IN MILS.

| Numbers. | Roebling. | Brown & Sharpe. | Birmingham or Stubs. | New British standard. |
|---|---|---|---|---|
| 000 000 | 460. | ..... | ..... | 464. |
| 00 000 | 430. | ..... | ..... | 432. |
| 0 000 | 393. | 460. | 454. | 400. |
| 000 | 362. | 409.6 | 425. | 372. |
| 00 | 331. | 364.8 | 380. | 348. |
| 0 | 307. | 324.9 | 340. | 324. |
| 1 | 283. | 289.3 | 300. | 300. |
| 2 | 263. | 257.6 | 284. | 276. |
| 3 | 244. | 229.4 | 259. | 252. |
| 4 | 225. | 204.3 | 238. | 232. |
| 5 | 207. | 181.9 | 220. | 212. |
| 6 | 192. | 162. | 203. | 192. |
| 7 | 177. | 144.3 | 180. | 176. |
| 8 | 162. | 128.5 | 165. | 160. |
| 9 | 148. | 114.4 | 148. | 144. |
| 10 | 135. | 101.9 | 134. | 128. |
| 11 | 120. | 90.74 | 120. | 116. |
| 12 | 105. | 80.81 | 109. | 104. |
| 13 | 92. | 71.96 | 95. | 92. |
| 14 | 80. | 64.08 | 83. | 80. |
| 15 | 72. | 57.07 | 72. | 72. |
| 16 | 63. | 50.82 | 65. | 64. |
| 17 | 54. | 45.26 | 58. | 56. |
| 18 | 47. | 40.3 | 49. | 48. |
| 19 | 41. | 35.89 | 42. | 40. |
| 20 | 35. | 31.96 | 35. | 36. |
| 21 | 32. | 28.46 | 32. | 32. |
| 22 | 28. | 25.35 | 28. | 28. |
| 23 | 25. | 22.57 | 25. | 24. |
| 24 | 23. | 20.1 | 22. | 22. |
| 25 | 20. | 17.9 | 20. | 20. |
| 26 | 18. | 15.94 | 18. | 18. |
| 27 | 17. | 14.2 | 16. | 16.4 |
| 28 | 16. | 12.64 | 14. | 14.8 |
| 29 | 15. | 11.26 | 13. | 13.6 |
| 30 | 14. | 10.03 | 12. | 12.4 |
| 31 | 13.5 | 8.93 | 10. | 11.6 |
| 32 | 13. | 7.95 | 9. | 10.8 |
| 33 | 11. | 7.08 | 8. | 10. |
| 34 | 10. | 6.3 | 7. | 9.2 |
| 35 | 9.5 | 5.62 | 5. | 8.4 |
| 36 | 9. | 5. | 4. | 7.6 |

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## WIRE GAUGES IN MILLIMETERS.

| Numbers. | Roebling. | Brown & Sharpe. | Birmingham or Stubs. | New British standard. |
|---|---|---|---|---|
| 000 000 | 11.683 | ..... | ..... | 11.785 |
| 00 000 | 10.921 | ..... | ..... | 10.972 |
| 0 000 | 9.982 | 11.683 | 11.531 | 10.16 |
| 000 | 9.195 | 10.404 | 10.794 | 9.448 |
| 00 | 8.407 | 9.266 | 9.652 | 8.839 |
| 0 | 7.798 | 8.251 | 8.636 | 8.229 |
| 1 | 7.188 | 7.348 | 7.62 | 7.62 |
| 2 | 6.68 | 6.544 | 7.213 | 7.01 |
| 3 | 6.198 | 5.827 | 6.579 | 6.401 |
| 4 | 5.715 | 5.19 | 6.045 | 5.893 |
| 5 | 5.257 | 4.621 | 5.588 | 5.385 |
| 6 | 4.877 | 4.115 | 5.156 | 4.877 |
| 7 | 4.496 | 3.665 | 4.572 | 4.47 |
| 8 | 4.115 | 3.263 | 4.191 | 4.064 |
| 9 | 3.759 | 2.906 | 3.759 | 3.657 |
| 10 | 3.429 | 2.588 | 3.404 | 3.251 |
| 11 | 3.048 | 2.305 | 3.048 | 2.947 |
| 12 | 2.667 | 2.052 | 2.768 | 2.641 |
| 13 | 2.337 | 1.828 | 2.413 | 2.337 |
| 14 | 2.032 | 1.628 | 2.108 | 2.032 |
| 15 | 1.829 | 1.449 | 1.829 | 1.829 |
| 16 | 1.6 | 1.291 | 1.651 | 1.626 |
| 17 | 1.372 | 1.15 | 1.473 | 1.422 |
| 18 | 1.194 | 1.024 | 1.245 | 1.219 |
| 19 | 1.041 | .911 6 | 1.067 | 1.016 |
| 20 | .889 | .811 8 | .889 | .914 4 |
| 21 | .812 8 | .722 9 | .812 8 | .812 8 |
| 22 | .711 2 | .643 8 | .711 2 | .711 2 |
| 23 | .635 | .573 3 | .635 | .609 6 |
| 24 | .584 2 | .510 5 | .558 8 | .558 8 |
| 25 | .508 | .454 6 | .508 | .508 |
| 26 | .457 2 | .404 9 | .457 2 | .457 2 |
| 27 | .431 8 | .360 5 | .406 4 | .416 6 |
| 28 | .406 4 | .321 1 | .355 6 | .375 9 |
| 29 | .381 | .285 9 | .330 2 | .345 4 |
| 30 | .355 6 | .254 5 | .304 8 | .315 |
| 31 | .342 9 | .226 7 | .254 | .294 6 |
| 32 | .330 2 | .201 9 | .228 6 | .274 3 |
| 33 | .279 4 | .179 8 | .203 2 | .254 |
| 34 | .254 | .160 1 | .177 8 | .233 7 |
| 35 | .241 3 | .142 6 | .127 | .213 4 |
| 36 | .228 6 | .127 | .101 6 | .193 |

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# TABLES OF SPECIFIC GRAVITIES.

## Metals.

| Names of metals. | Specific gravity. | Weights per cubic foot. | Specific heat. | Melting point in degrees Fahrenheit. |
|---|---|---|---|---|
| Aluminum, cast | 2.5[1] | 156.06 | .214 3 | ..... |
| " hammered. | 2.67[1] | 166.67 | ..... | ..... |
| Antimony | 6.702[2] | 418.37 | .050 8 | 810. |
| Arsenic | 5.763[2] | 359.76 | .081 4 | 365. |
| Barium | 4.[3] | 249.7 | ..... | ..... |
| Bismuth | 9.822[2] | 613.14 | .030 8 | 497. |
| Cadmium | 8.604[2] | 537.1 | .056 7 | 500. |
| Calcium | 1.566[4] | 97.76 | ..... | ..... |
| Chromium | 7.3[6] | 455.7 | ..... | ..... |
| Cobalt | 8.6 | 536.86 | .107 | ..... |
| Copper | 8.895[7] | 555.27 | .095 1 | 1 996. |
| " rolled | 8.878[2] | 554.21 | ..... | ..... |
| " cast | 8.788[2] | 548.59 | ..... | ..... |
| " drawn | 8.946 3[6] | 558.47 | ..... | ..... |
| " hammered | 8.958 7[6] | 559.25 | ..... | ..... |
| " pressed | 8.931[9] | 557 52 | ..... | ..... |
| " electrolytic | 8.914[9] | 556.46 | ..... | ..... |
| Gold | 19.258[2] | 1 202.18 | .032 4 | 2 016. |
| Iron, bar | 7.483[9] | 467.18 | .13 | 2 786. |
| " wrought | 7.79 | 486.29 | .113 | 3 286. |
| Steel | 7.85 | 490.03 | .116 | 3 286. |
| Lead | 11 445[10] | 714.45 | .031 4 | 612. |
| Magnesium | 2.24[11] | 139.83 | .249 9 | ..... |
| Manganese | 6.9[12] | 430.73 | .114 | 3 000. |
| Mercury | 13.568[13] | 846.98 | .031 9 | — 38. |
| Nickel | 7.832 | 488.91 | .109 1 | 280 0. |
| Platinum | 20.3[3] | 1 267.22 | .032 4 | 328 6. |
| Potassium | .865[14] | 54. | .169 6 | 136. |
| Silver | 10.522[11] | 656.84 | .057 | 1 873. |
| Sodium | .972[14] | 60.68 | .293 4 | 194. |
| Strontium | 2.504[4] | 156.31 | ..... | ..... |
| Tin | 7.291[2] | 455.14 | .056 2 | 442. |
| Zinc | 6.861[2] | 428.29 | .095 5 | 773. |

1. Wöhler.
2. Brisson.
3. Clarke.
4. Matthiessen.
5. Stromeyer.
6. Bunsen.
7. Hatchett.
8. Brezenius.
9. Marchand & Scheerer.
10. Musschenbroek.
11. Playfair & Joule.
12. Bergman.
13. Watts' Dictionary.
14. Gay-Lussac & Thenard.

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## TABLES OF SPECIFIC GRAVITIES.—(*Cont.*)

### Liquids.

| Names of liquids. | Specific gravity. | Temperatures. |
|---|---|---|
| Alcohol | 0.815 71 | At 50° F. |
| Benzine | 0.883 | At 59° F. |
| Chloroform | 1.491 | At 62.6° F. |
| Carbon bisulphide | 1.293 1 | At 32° F. |
| Ether | 0.720 4 | At 60.8° F. |
| Glycerine | 1.263 6 | At 59° F. |
| Hydrochloric acid | 1.27 | ..... |
| Mercury | 13.596 | At 32° F. |
| Nitric acid | 1.552 | At 59° F. |
| Oil of turpentine | 0.855 to 0.864 | At 68° F. |
| Linseed oil | 0.94 | ..... |
| Olive oil | 0.915 | ..... |
| Sulphuric acid | 1.854 | At 32° F. |

### Gases.

| Names of gases. | At 0° C. and 760 mm. pressure compared to water. | At 0° C. and 760 mm. pressure compared to air. |
|---|---|---|
| Air | 0.001 292 8 | 1. |
| Oxygen | 0.001 429 3 | 1.105 63 |
| Nitrogen | 0.001 255 7 | 0.971 37 |
| Hydrogen | 0.000 089 54 | 0.069 26 |
| Carbonic dioxide | 0.001 976 7 | 1.529 1 |
| Mixed gases from electrolysis of water | 0.000 536 1 | 0.414 72 |
| Aqueous vapor | ..... | 0.623 |

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## WEIGHTS OF SUBSTANCES.

| Names of substances. | Average weights per cubic foot. Pounds. |
|---|---|
| Asphaltum | 87. |
| Brick, common, hard | 125. |
| Brickwork, pressed brick | 140. |
| " ordinary | 112. |
| Coal, anthracite, solid, of Pennsylvania | 93. |
| " " broken, loose | 54. |
| " bituminous, solid | 84. |
| " " broken, loose | 49. |
| Coke, loose, of good coal | 62. |
| Cork | 12.4 |
| Earth, common loam, dry, loose | 76. |
| " " " " moderately rammed | 95. |
| " as a soft, flowing mud | 108. |
| Gneiss, common | 168. |
| Granite | 170. |
| Glass, Crown | 168.5 |
| " flint | 218.3 |
| Ice at 0° C | 57.2 |
| Lime, thoroughly shaken | 75. |
| Masonry, of granite or limestone, well dressed | 165. |
| Mortar, hardened | 103. |
| Mud, dry, close | 80 to 1 |
| Quartz | 165.4 |
| Sulphur | 131. |
| Wax | 58.7 |
| Wood, ebony | 74.9 |
| " birch | 43.7 |
| " oak | 46.8 |
| " pine | 31.2 |
| Water at 32° F | 62.418 |
| " " 39.1° F | 62.425 |
| " " 50° F | 62.409 |
| " " 60° F | 62.367 |
| " " 70° F | 62.302 |
| " " 80° F | 62.218 |
| " " 90° F | 62.119 |

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# THE COMPARISON OF THERMOMETERS.

## Fahrenheit to Centigrade.

$(t° F. - 32) \times \frac{5}{9} = \text{Degrees C.}$

| Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. |
|---|---|---|---|---|---|---|---|---|---|
| 50 | 10. | 61 | 16.1 | 72 | 22.2 | 83 | 28.3 | 94 | 34.4 |
| 51 | 10.6 | 62 | 16.7 | 73 | 22.8 | 84 | 28.9 | 95 | 35. |
| 52 | 11.1 | 63 | 17.2 | 74 | 23.3 | 85 | 29.4 | 96 | 35.6 |
| 53 | 11.7 | 64 | 17.8 | 75 | 23.9 | 86 | 30. | 97 | 36.1 |
| 54 | 12.2 | 65 | 18.3 | 76 | 24.4 | 87 | 30.6 | 98 | 36.7 |
| 55 | 12.8 | 66 | 18.9 | 77 | 25. | 88 | 31.1 | 99 | 37.2 |
| 56 | 13.3 | 67 | 19.4 | 78 | 25.6 | 89 | 31.7 | 100 | 37.8 |
| 57 | 13.9 | 68 | 20. | 79 | 26.1 | 90 | 32.2 | | |
| 58 | 14.4 | 69 | 20.6 | 80 | 26.7 | 91 | 32.8 | | |
| 59 | 15. | 70 | 21.1 | 81 | 27.2 | 92 | 33.3 | | |
| 60 | 15.6 | 71 | 21.7 | 82 | 27.8 | 93 | 33.9 | | |

## Centigrade to Fahrenheit.

$\frac{9}{5}\ t° C + 32 = \text{Degrees F.}$

| Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. | Centigrade. | Fahrenheit. |
|---|---|---|---|---|---|---|---|
| 10 | 50. | 18 | 64.4 | 26 | 78.8 | 34 | 93.2 |
| 11 | 51.8 | 19 | 66.2 | 27 | 80.6 | 35 | 95. |
| 12 | 53.6 | 20 | 68. | 28 | 82.4 | 36 | 96.8 |
| 13 | 55.4 | 21 | 69.8 | 29 | 84.2 | 37 | 98.6 |
| 14 | 57.2 | 22 | 71.6 | 30 | 86. | 38 | 100.4 |
| 15 | 59. | 23 | 73.4 | 31 | 87.8 | 39 | 102.2 |
| 16 | 60.8 | 24 | 75.2 | 32 | 89.6 | 40 | 104. |
| 17 | 62.6 | 25 | 77. | 33 | 91.4 | | |

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## ELECTRICAL UNITS.

**Final and official recommendation of the Chamber of Delegates of the International Electrical Congress, held at Chicago, 1893.**

*Resolved*, That the several governments represented by the delegates of this International Congress of Electricians be, and they are hereby, recommended to formally adopt as legal units of electrical measure the following: As a unit of resistance, the *international ohm*, which is based upon the ohm equal to $10^9$ units of resistance of the C. G. S. system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.452 1 grams in mass, of a constant cross-sectional area and of the length of 106.3 centimeters.

As a unit of current, the *international ampere*, which is one-tenth of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications,[1] deposits silver at the rate of 0.001 118 of a gram per second.

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1. In the following specification the term silver voltameter means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time average of the current, or, if the current has been kept constant, the current itself can be deduced.

In employing the silver voltameter to measure currents of about one ampere, the following arrangements should be adopted:

The kathode on which the silver is to be deposited should take the form of a platinum bowl not less than 10 centimeters in diameter and from 4 to 5 centimeters in depth.

The anode should be a plate of pure silver, some 30 square centimeters in area and 2 or 3 millimeters in thickness.

This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the anode from falling onto the kathode, the anode should be wrapped around with pure filter paper, secured at the back with sealing wax.

The liquid should consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current

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As a unit of electro-motive force, the *international volt*, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the accompanying specification.[2]

As a unit of quantity, the *international coulomb*, which is the quantity of electricity transferred by a current of one international ampere in one second.

As a unit of capacity, the *international farad*, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

As a unit of work, the *joule*, which is equal to $10^7$ units of work in the C. G. S. system, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampere in an international ohm.

As a unit of power, the *watt*, which is equal to $10^7$ units of power in the C. G. S. system, and which is represented sufficiently well for practical use by work done at the rate of one joule per second.

As the unit of induction, the *henry*, which is the induction in a circuit when the electro-motive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second.

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passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

2. A committee, consisting of Messrs. Helmholtz, Ayrton and Carhart, was appointed to prepare specifications for the Clark's cell. Their report has not yet been received.

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# COPPER WIRE.

IN THE following tables of copper wire the value of the mil-foot is taken as the standard.

The temperature coëfficient is interpolated for 60° F. and 75° F. from the values given in the second table.

In the table for B. & S. G., the actual sizes to which wire is drawn, are used.

In many cases the nearest whole number of pounds is taken when the variation is less than that found in actual weights of drawn wire.

In computing the weights, the specific gravity of copper is taken at 8.89, water being at its greatest density 62.425 pounds per cubic foot.

International ohms are used, unless the kind of unit is specifically stated.

The following formulæ were used:

$$\text{Resistance per 1 000 feet at 60° F.} = \frac{10\,180.694}{d^2}.$$

$$\text{Resistance per 1 000 feet at 75° F.} = \frac{10\,507.4}{d^2}.$$

$$\text{Weight per 1 000 feet} = .003\,027 \times d^2.$$

$$\text{Weight per mile} = .015\,983 \times d^2.$$

The following data and formulæ may be useful:

One B. A. unit = .988 9 legal ohms = .986 6 International ohms.
One legal ohm = 1.011 22 B. A. units = .997 67 International ohms.
One International ohm = 1.013 58 B. A. units = 1.002 33 legal ohms.
One cubic foot of copper weighs 555 pounds.
One cubic inch of copper weighs .321 2 pounds.

$$\text{Resistance per 1 000 feet at 60° F.} = \frac{30.815}{\text{weight per 1 000 feet.}}$$

$$\text{Resistance per 1 000 feet at 75° F.} = \frac{31.804}{\text{weight per 1 000 feet.}}$$

If a copper wire of length l, diameter d, and weight w, has a resistance R at temperature t, then its conductivity

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by diameter is given by the first formula, and by weight by the second.

$$C = \frac{a\,l\,k}{d^2\,R.} \qquad R\,t^\circ = \frac{a\,l\,k}{d^2.}$$

$$C = \frac{b\,l^2\,c}{w\,R.} \qquad R\,t^\circ = \frac{b\,l^2\,c}{w.}$$

Here, a is the resistance of a mil-foot in same units as R, k is the temperature coëfficient for t° Centigrade, and b is the resistance of one meter-gram at temperature t° and in same units as R.

When l is in meters and w in grams, c = 1.
When l is in feet and w in grams, c = .092 9.
When l is in feet and w in pounds, c = .000 204 8.

Mile-ohm = weight per mile × resistance per mile.

Mile-ohm at 60° = 859, International ohms.
Mile-ohm at 60° = 868.9, B. A. units.
Mile-ohm at 60° = 861, Legal ohms.

The following tables are taken from the report of the Standard Wiring Table Committee, published in the report of the meeting of the American Institute of Electrical Engineers, held January 17, 1893:

## MATTHIESSEN'S STANDARD.

(Recommended by the Committee).

| Equivalent length of a square mm. mercury column. | B. A. units. | Legal ohms. | International ohms. |
|---|---|---|---|
| | 104.8 cms. | 106.0 cms. | 106.3 cms. |
| Resistance at 0° C. of Matthiessen's Standard— | | | |
| Meter-gram soft copper | .143 65 | .142 06 | .141 73 |
| Meter-millimeter soft copper | .020 57 | .020 35 | .020 3 |
| Cubic centimeter soft copper | .000 001 616 | .000 001 598 | .000 001 594 |
| Mil-foot soft copper | 9.72 | 9.612 | 9.59 |

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## TEMPERATURE COËFFICIENTS.

**Table of temperature variations in the resistance of pure soft copper according to Matthiessen's standard and formulæ.**

| Temperature in degrees Centigrade. | Temperature coefficient of resistance. | Logarithm. | Matthiessen meter-gram standard resistance. | | |
|---|---|---|---|---|---|
| | | | B. A. units. | Legal ohms. | International ohms. |
| 0 | 1. | 0. | 0.143 65 | 0.142 06 | 0.141 73 |
| 1 | 1.003 876 | 0.001 680 1 | 0.144 21 | 0.142 61 | 0.142 28 |
| 2 | 1.007 764 | 0.003 358 8 | 0.144 77 | 0.143 17 | 0.142 83 |
| 3 | 1.011 66 | 0.005 036 2 | 0.145 33 | 0.143 72 | 0.143 38 |
| 4 | 1.015 58 | 0.006 712 1 | 0.145 89 | 0.144 27 | 0.143 94 |
| 5 | 1.019 5 | 0.008 386 4 | 0.146 45 | 0.144 83 | 0.144 49 |
| 6 | 1.023 43 | 0.010 059 3 | 0.147 02 | 0.145 39 | 0.145 05 |
| 7 | 1.027 38 | 0.011 730 7 | 0.147 59 | 0.145 95 | 0.145 61 |
| 8 | 1.031 34 | 0.013 400 3 | 0.148 15 | 0.146 51 | 0.146 17 |
| 9 | 1.035 31 | 0.015 068 3 | 0.148 73 | 0.147 08 | 0.146 73 |
| 10 | 1.039 29 | 0.016 734 6 | 0.149 3 | 0.147 64 | 0.147 3 |
| 11 | 1.043 28 | 0.018 399 3 | 0.149 87 | 0.148 21 | 0.147 86 |
| 12 | 1.047 28 | 0.020 062 1 | 0.150 45 | 0.148 78 | 0.148 43 |
| 13 | 1.051 29 | 0.021 723 | 0.151 02 | 0.149 35 | 0.149 |
| 14 | 1.055 32 | 0.023 382 1 | 0.151 6 | 0.149 92 | 0.149 57 |
| 15 | 1.059 35 | 0.025 039 | 0.152 18 | 0.150 49 | 0.150 14 |
| 16 | 1.063 39 | 0.026 694 | 0.152 77 | 0.151 07 | 0.150 71 |
| 17 | 1.067 45 | 0.028 348 | 0.153 34 | 0.151 64 | 0.151 29 |
| 18 | 1.071 52 | 0.029 999 | 0.153 93 | 0.152 22 | 0.151 86 |
| 19 | 1.075 59 | 0.803 164 | 0.154 51 | 0.152 8 | 0.152 44 |
| 20 | 1.079 68 | 0.033 294 | 0.155 1 | 0.153 38 | 0.153 02 |
| 21 | 1.083 78 | 0.034 939 | 0.155 69 | 0.153 96 | 0.153 6 |
| 22 | 1.087 88 | 0.036 581 | 0.156 28 | 0.154 55 | 0.154 18 |
| 23 | 1.092 | 0.038 222 | 0.156 87 | 0.155 13 | 0.154 77 |
| 24 | 1.096 12 | 0.039 859 | 0.157 46 | 0.155 72 | 0.155 35 |
| 25 | 1.100 26 | 0.041 494 | 0.158 06 | 0.156 31 | 0.155 94 |
| 26 | 1.104 4 | 0.043 127 | 0.158 65 | 0.156 89 | 0.156 53 |
| 27 | 1.108 56 | 0.044 758 | 0.159 25 | 0.157 48 | 0.157 11 |
| 28 | 1.112 72 | 0.046 385 | 0.159 85 | 0.158 08 | 0.157 7 |
| 29 | 1.116 89 | 0.048 011 | 0.160 44 | 0.158 67 | 0.158 3 |
| 30 | 1.121 07 | 0.049 633 | 0.161 05 | 0.159 26 | 0.158 89 |
| 40 | 1.163 32 | 0.065 699 | 0.167 11 | 0.165 26 | 0.164 88 |
| 50 | 1.206 25 | 0.081 436 | 0.173 28 | 0.171 36 | 0.170 95 |
| 60 | 1.249 65 | 0.096 787 | 0.179 52 | 0.177 53 | 0.177 11 |
| 70 | 1.293 27 | 0.111 687 | 0.185 78 | 0.183 72 | 0.183 29 |
| 80 | 1.336 81 | 0.126 069 | 0.192 04 | 0.189 91 | 0.189 46 |
| 90 | 1.379 95 | 0.139 863 | 0.198 23 | 0.196 04 | 0.195 58 |
| 100 | 1 422 31 | 0.152 995 | 0.204 32 | 0.202 06 | 0.201 58 |

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# PROPERTIES OF COPPER WIRE.

## English system—Brown & Sharpe gauge.

| Numbers. | Diameters in mils. | Areas in circular mils. C. M. = d². | Weights. | | Resistances per 1 000 feet in International ohms. | |
|---|---|---|---|---|---|---|
| | | | 1 000 feet. | Mile. | At 60° F. | At 75° F. |
| 0 000 | 460. | 211 600. | 641. | 3 382. | .048 11 | .049 66 |
| 000 | 410. | 168 100. | 509. | 2 687. | .060 56 | .062 51 |
| 00 | 365. | 133 225. | 403. | 2 129. | .076 42 | .078 87 |
| 0 | 325. | 105 625. | 320. | 1 688. | .096 39 | .099 48 |
| 1 | 289. | 83 521. | 253. | 1 335. | .121 9 | .125 8 |
| 2 | 258. | 66 564. | 202. | 1 064. | .152 9 | .157 9 |
| 3 | 229. | 52 441. | 159. | 838. | .194 1 | .200 4 |
| 4 | 204. | 41 616. | 126. | 665. | .244 6 | .252 5 |
| 5 | 182. | 33 124. | 100. | 529. | .307 4 | .317 2 |
| 6 | 162. | 26 244. | 79. | 419. | .387 9 | .400 4 |
| 7 | 144. | 20 736. | 63. | 331. | .491 | .506 7 |
| 8 | 128. | 16 384. | 50. | 262. | .621 4 | .641 3 |
| 9 | 114. | 12 996. | 39. | 208. | .783 4 | .808 5 |
| 10 | 102. | 10 404. | 32. | 166. | .978 5 | 1.01 |
| 11 | 91. | 8 281. | 25. | 132. | 1.229 | 1.269 |
| 12 | 81. | 6 561. | 20. | 105. | 1.552 | 1.601 |
| 13 | 72. | 5 184. | 15.7 | 83. | 1.964 | 2.027 |
| 14 | 64. | 4 096. | 12.4 | 65. | 2.485 | 2.565 |
| 15 | 57. | 3 249. | 9.8 | 52. | 3.133 | 3.234 |
| 16 | 51. | 2 601. | 7.9 | 42. | 3.914 | 4.04 |
| 17 | 45. | 2 025. | 6.1 | 32. | 5.028 | 5.189 |
| 18 | 40. | 1 600. | 4.8 | 25.6 | 6.363 | 6.567 |
| 19 | 36. | 1 296. | 3.9 | 20.7 | 7.855 | 8.108 |
| 20 | 32. | 1 024. | 3.1 | 16.4 | 9.942 | 10.26 |
| 21 | 28.5 | 812.3 | 2.5 | 13. | 12.53 | 12.94 |
| 22 | 25.3 | 640.1 | 1.9 | 10.2 | 15.9 | 16.41 |
| 23 | 22.6 | 510.8 | 1.5 | 8.2 | 19.93 | 20.57 |
| 24 | 20.1 | 404. | 1.2 | 6 5 | 25.2 | 26.01 |
| 25 | 17.9 | 320.4 | .97 | 5.1 | 31.77 | 32.79 |
| 26 | 15.9 | 252.8 | .77 | 4. | 40.27 | 41.56 |
| 27 | 14.2 | 201.6 | .61 | 3.2 | 50.49 | 52.11 |
| 28 | 12.6 | 158.8 | .48 | 2.5 | 64.13 | 66.18 |
| 29 | 11.3 | 127.7 | .39 | 2. | 79.73 | 82.29 |
| 30 | 10. | 100. | .3 | 1.6 | 101.8 | 105.1 |
| 31 | 8.9 | 79.2 | .24 | 1.27 | 128.5 | 132.7 |
| 32 | 8. | 64. | .19 | 1.02 | 159.1 | 164.2 |
| 33 | 7.1 | 50.4 | .15 | .81 | 202. | 208.4 |
| 34 | 6.3 | 39.7 | .12 | .63 | 256.5 | 264.7 |
| 35 | 5.6 | 31.4 | .095 | .5 | 324.6 | 335.1 |
| 36 | 5. | 25. | .076 | .4 | 407.2 | 420.3 |

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## PROPERTIES OF COPPER WIRE.—(*Cont.*)

**English system—Birmingham wire gauge.**

| Numbers. | Diameters in mils. | Areas in circular mils. C. M. = d². | Weights. | | Resistances per 1 000 feet in International ohms. | |
|---|---|---|---|---|---|---|
| | | | 1 000 feet. | Mile. | At 60° F. | At 75° F. |
| 0 000 | 454. | 206 116. | 624. | 3 294. | .049 39 | .050 98 |
| 000 | 425. | 180 625. | 547. | 2 887. | .056 36 | .058 17 |
| 00 | 380. | 144 400. | 437. | 2 308. | .070 5 | .072 77 |
| 0 | 340. | 115 600. | 350. | 1 847. | .088 07 | .090 89 |
| 1 | 300. | 90 000. | 272. | 1 438. | .113 1 | .116 7 |
| 2 | 284. | 80 656. | 244. | 1 289. | .126 2 | .130 3 |
| 3 | 259. | 67 081. | 203. | 1 072. | .151 8 | .156 6 |
| 4 | 238. | 56 644. | 171. | 905. | .179 7 | .185 5 |
| 5 | 220. | 48 400. | 146. | 773. | .210 3 | .217 1 |
| 6 | 203. | 41 209. | 125. | 659. | .247 1 | .255 |
| 7 | 180. | 32 400. | 98. | 518. | .314 2 | .324 3 |
| 8 | 165. | 27 225. | 82. | 435. | .373 9 | .385 9 |
| 9 | 148. | 21 904. | 66. | 350. | .464 8 | .479 7 |
| 10 | 134. | 17 956. | 54. | 287. | .567 | .585 2 |
| 11 | 120. | 14 400. | 44. | 230. | .707 | .729 7 |
| 12 | 109. | 11 881. | 36. | 190. | .856 9 | .884 4 |
| 13 | 95. | 9 025. | 27.3 | 144. | 1.128 | 1.164 |
| 14 | 83. | 6 889. | 20.8 | 110. | 1.478 | 1.525 |
| 15 | 72. | 5 184. | 15.7 | 83. | 1.964 | 2.027 |
| 16 | 65. | 4 225. | 12.8 | 68. | 2.41 | 2 487 |
| 17 | 58. | 3 364. | 10.2 | 54 | 3.026 | 3.123 |
| 18 | 49. | 2 401. | 7.3 | 38.4 | 4.24 | 4.376 |
| 19 | 42. | 1 764. | 5.3 | 28.2 | 5.771 | 5.957 |
| 20 | 35. | 1 225. | 3.7 | 19.6 | 8.311 | 8.577 |
| 21 | 32. | 1 024. | 3.1 | 16.4 | 9.942 | 10 26 |
| 22 | 28. | 784. | 2.4 | 12.5 | 12.99 | 13.4 |
| 23 | 25. | 625. | 1.9 | 10. | 16.29 | 16.81 |
| 24 | 22. | 484. | 1.5 | 7.7 | 21.03 | 21.71 |
| 25 | 20. | 400. | 1.2 | 6.4 | 25.45 | 26.27 |
| 26 | 18. | 324. | .98 | 5 2 | 31.42 | 32.43 |
| 27 | 16. | 256. | .77 | 4.1 | 39.77 | 41.04 |
| 28 | 14. | 196. | .59 | 3.1 | 51.94 | 53.61 |
| 29 | 13. | 169. | .51 | 2.7 | 60.24 | 62.17 |
| 30 | 12. | 144. | .44 | 2.3 | 70.7 | 72.97 |
| 31 | 10. | 100. | .3 | 1 6 | 108. | 105.1 |
| 32 | 9. | 81. | .25 | 1.3 | 125.7 | 129.7 |
| 33 | 8. | 64. | .19 | 1.02 | 159.1 | 164.2 |
| 34 | 7. | 49. | .15 | .78 | 207.8 | 214.4 |
| 35 | 5. | 25. | .075 | .4 | 407.2 | 420.3 |
| 36 | 4. | 16. | .048 | .256 | 636.3 | 656.7 |

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## PROPERTIES OF COPPER WIRE.—(*Cont.*)

**English system—New British standard gauge.**

| Numbers. | Diameters in mils. | Areas in Circular mils. C M. = d². | Weights. | | Resistances per 1 000 feet in International ohms. | |
|---|---|---|---|---|---|---|
| | | | 1 000 feet. | Mile. | At 60° F. | At 75° F. |
| 000 000 | 464. | 215 296. | 652. | 3 441. | .047 29 | .048 8 |
| 00 000 | 432. | 186 624. | 565. | 2 983. | .054 55 | .056 3 |
| 0 000 | 400. | 160 000. | 484. | 2 557. | .063 63 | .065 67 |
| 000 | 372. | 138 384. | 419. | 2 212. | .073 57 | .075 93 |
| 00 | 348. | 121 104. | 367. | 1 935. | .084 07 | .086 76 |
| 0 | 324. | 104 976. | 318. | 1 678. | .969 8 | .100 09 |
| 1 | 300. | 90 000. | 272. | 1 438. | .113 1 | .116 7 |
| 2 | 276. | 76 176. | 231. | 1 217. | .133 6 | .137 9 |
| 3 | 252. | 63 504. | 192. | 1 015. | .160 3 | .165 5 |
| 4 | 232. | 53 824. | 163. | 860. | .189 2 | .195 2 |
| 5 | 212. | 44 944. | 136. | 718. | .226 5 | .233 8 |
| 6 | 192. | 36 864. | 112. | 589. | .276 2 | .285 |
| 7 | 176. | 30 976. | 94. | 495. | .328 7 | .339 2 |
| 8 | 160. | 25 600. | 77. | 409. | .397 7 | .410 4 |
| 9 | 144. | 20 736. | 63. | 331. | .491 | .506 7 |
| 10 | 128. | 16 384. | 50. | 262. | .621 4 | .641 3 |
| 11 | 116. | 13 456. | 41. | 215. | .756 6 | .780 9 |
| 12 | 104. | 10 816. | 33. | 173. | .941 3 | .971 5 |
| 13 | 92. | 8 464. | 25.6 | 135. | 1 203 | 1.241 |
| 14 | 80. | 6 400. | 19.4 | 102. | 1.591 | 1.642 |
| 15 | 72. | 5 184. | 15.7 | 83. | 1.964 | 2.027 |
| 16 | 64. | 4 096. | 12.4 | 65. | 2.486 | 2.565 |
| 17 | 56. | 3 136. | 9.5 | 50. | 3.246 | 3.351 |
| 18 | 48. | 2 304. | 7. | 36.8 | 4.419 | 4.561 |
| 19 | 40. | 1 600. | 4.8 | 25.6 | 6.363 | 6.567 |
| 20 | 36. | 1 296. | 3.9 | 20.7 | 7.855 | 8.108 |
| 21 | 32. | 1 024. | 3.1 | 16.4 | 9.942 | 10.26 |
| 22 | 28. | 784. | 2.4 | 12.5 | 12.99 | 13.4 |
| 23 | 24. | 576. | 1.7 | 9.2 | 17.67 | 18.24 |
| 24 | 22. | 484. | 1.5 | 7.7 | 21.03 | 21.71 |
| 25 | 20. | 400. | 1.2 | 6.4 | 25.45 | 26.27 |
| 26 | 18. | 324. | .96 | 5.2 | 31.42 | 32.43 |
| 27 | 16.4 | 269. | .81 | 4.3 | 37.85 | 39.07 |
| 28 | 14.8 | 219. | .66 | 3.5 | 46.48 | 47.97 |
| 29 | 13.6 | 185. | .56 | 3. | 55.04 | 56.81 |
| 30 | 12.4 | 153.8 | .47 | 2.5 | 66.21 | 68.34 |
| 31 | 11.6 | 134.6 | .41 | 2.15 | 75.66 | 78.09 |
| 32 | 10.8 | 116.6 | .35 | 1.86 | 87.28 | 90.08 |
| 33 | 10. | 100. | .3 | 1.6 | 101.8 | 105.1 |
| 34 | 9.2 | 84.6 | .26 | 1.35 | 120.3 | 124.1 |
| 35 | 8.4 | 70.6 | .21 | 1.13 | 144.3 | 148.9 |
| 36 | 7.6 | 57.8 | .17 | .92 | 176.3 | 181.9 |

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## PROPERTIES OF COPPER WIRE.—(*Cont.*)

**Metric system—Brown & Sharpe gauge.**

| Numbers. | Diameters in millimeters. | Areas in square millimeters. | Weights per kilometer in kilograms. | Resistances per kilometer in International ohms. | |
|---|---|---|---|---|---|
| | | | | At 60° F. | At 75° F. |
| 0 000 | 11.683 | 107.2 | 954.3 | .157 8 | .162 9 |
| 000 | 10.404 | 85.01 | 756.8 | .198 7 | .205 1 |
| 00 | 9.266 | 67.43 | 600.2 | .250 7 | .258 8 |
| 0 | 8.251 | 53.47 | 480.4 | .316 2 | .326 4 |
| 1 | 7.348 | 42.41 | 377.4 | .399 9 | .412 7 |
| 2 | 6.544 | 33.63 | 299.3 | .501 8 | .517 9 |
| 3 | 5.827 | 26.67 | 237.4 | .636 9 | .657 4 |
| 4 | 5.19 | 21.16 | 188.3 | .802 6 | .828 4 |
| 5 | 4.621 | 16.77 | 149.3 | 1.009 | 1.041 |
| 6 | 4.115 | 13.3 | 118.4 | 1.273 | 1.314 |
| 7 | 3.665 | 10.55 | 93.9 | 1.611 | 1.662 |
| 8 | 3.263 | 8.362 | 74.5 | 2.039 | 2.104 |
| 9 | 2.906 | 6.633 | 59. | 2.57 | 2.653 |
| 10 | 2.588 | 5.26 | 46.8 | 3.21 | 3.313 |
| 11 | 2.305 | 4.173 | 37.1 | 4.033 | 4.163 |
| 12 | 2.052 | 3.307 | 29.5 | 5.091 | 5.253 |
| 13 | 1.828 | 2.625 | 23.4 | 6.443 | 6.65 |
| 14 | 1.628 | 2.082 | 18.5 | 8.155 | 8.416 |
| 15 | 1.449 | 1.649 | 14.7 | 10.28 | 10.61 |
| 16 | 1.291 | 1.309 | 11.7 | 12.84 | 13.25 |
| 17 | 1.15 | 1.039 | 9.23 | 16.5 | 17.02 |
| 18 | 1.024 | .823 6 | 7.32 | 20.88 | 21.55 |
| 19 | .911 6 | .652 7 | 5.8 | 25.77 | 26.6 |
| 20 | .811 8 | .517 6 | 4.61 | 32.62 | 33.66 |
| 21 | .722 9 | .410 4 | 3.65 | 41.11 | 42.45 |
| 22 | .643 8 | .325 5 | 2.89 | 52.16 | 53.84 |
| 23 | .573 3 | .258 1 | 2.16 | 65.39 | 67.49 |
| 24 | .510 5 | .204 7 | 1.82 | 82.68 | 85.33 |
| 25 | .454 6 | .162 3 | 1.44 | 104.2 | 107.6 |
| 26 | .404 9 | .128 8 | 1.15 | 132.1 | 136.3 |
| 27 | .360 5 | .102 1 | .908 | 165.1 | 171. |
| 28 | .321 1 | .081 | .72 | 210.4 | 217.1 |
| 29 | .285 9 | .064 2 | .572 | 261.6 | 270. |
| 30 | .254 5 | .050 9 | .452 | 334. | 344.8 |
| 31 | .226 7 | .040 4 | .359 | 421.6 | 435.4 |
| 32 | .201 9 | .032 | .284 | 522. | 538.7 |
| 33 | .179 8 | .025 4 | .226 | 662.7 | 683.7 |
| 34 | .160 1 | .020 1 | .179 | 841.5 | 868.4 |
| 35 | .142 6 | .016 | .141 | 1 065. | 1 099. |
| 36 | .127 | .012 7 | .113 | 1 336. | 1 379. |

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# WEIGHTS OF COPPER WIRE.

**Metric system—per kilometer, in kilograms.**

| Numbers. | Roebling. | Brown & Sharpe. | Birmingham or Stubs. | New British standard. |
|---|---|---|---|---|
| 000 000 | 954.3 | ..... | ..... | 970.9 |
| 00 000 | 833.9 | ..... | ..... | 841.6 |
| 0 000 | 696.5 | 964.3 | 929.4 | 721.5 |
| 000 | 591. | 756.8 | 814.5 | 624. |
| 00 | 494.1 | 600.2 | 651.3 | 546.2 |
| 0 | 425.1 | 480.4 | 521.3 | 473.4 |
| 1 | 361.2 | 377.4 | 405.8 | 405.8 |
| 2 | 311.9 | 299.3 | 363.3 | 343.5 |
| 3 | 268.5 | 237.4 | 302.6 | 286.3 |
| 4 | 228.3 | 188.3 | 255.3 | 242.7 |
| 5 | 193.2 | 149.3 | 218.3 | 202.7 |
| 6 | 166.2 | 118.4 | 185.9 | 166.2 |
| 7 | 141.3 | 93.9 | 146.1 | 139.7 |
| 8 | 118.3 | 74.5 | 122.8 | 115 4 |
| 9 | 98.8 | 59. | 98.8 | 93.5 |
| 10 | 82.2 | 46.8 | 81. | 73.9 |
| 11 | 64.9 | 37.1 | 64.9 | 60.7 |
| 12 | 49.9 | 29.5 | 53.6 | 48.8 |
| 13 | 38.2 | 23.4 | 39.8 | 38 2 |
| 14 | 28.9 | 18.5 | 31.1 | 28.9 |
| 15 | 23.4 | 14.7 | 23.4 | 23.4 |
| 16 | 17.9 | 11.7 | 19.1 | 18.5 |
| 17 | 13.2 | 9.23 | 15.2 | 14.1 |
| 18 | 9.96 | 7.32 | 10.8 | 10.4 |
| 19 | 7.58 | 5.8 | 7.95 | 7.22 |
| 20 | 5.52 | 4.61 | 5.52 | 5.85 |
| 21 | 4.61 | 3.65 | 4.62 | 4.61 |
| 22 | 3.54 | 2.89 | 3.54 | 3.54 |
| 23 | 2.81 | 2.16 | 2.81 | 2.59 |
| 24 | 2.38 | 1.82 | 2.19 | 2.19 |
| 25 | 1.8 | 1.44 | 1.8 | 1.8 |
| 26 | 1.46 | 1.15 | 1.46 | 1.46 |
| 27 | 1.3 | .908 | 1.16 | 1.21 |
| 28 | 1.15 | .72 | .884 | .988 |
| 29 | 1.02 | .572 | .762 | .833 |
| 30 | .884 | .452 | .649 | .694 |
| 31 | .822 | .359 | .451 | .607 |
| 32 | .762 | .284 | .365 | .525 |
| 33 | .544 | .226 | .289 | .451 |
| 34 | .451 | .179 | .22 | .381 |
| 35 | .406 | .141 | .113 | .319 |
| 36 | .365 | .113 | .071 | .26 |

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## HARD-DRAWN COPPER WIRE.

**British Post-office specifications.**

| Diameters. | | | Weights per mile. | | | Minimum breaking strain. Pounds. | Minimum twists. | Maximum resistance per mile at 60° F. International ohms. |
|---|---|---|---|---|---|---|---|---|
| Required. | Maximum. | Minimum. | Required. | Maximum. | Minimum. | | | |
| 224 | 226 | 220 1/2 | 800 | 820 | 780 | 2400 | in 6 in. { 15 | 1.098 |
| 194 | 196 | 191 | 600 | 615 | 585 | 1800 | in 6 in. { 20 | 1.464 |
| 158 | 160 1/4 | 155 1/2 | 400 | 410 | 390 | 1300 | in 6 in. { 25 | 2.195 |
| 112 | 113 1/4 | 110 1/2 | 200 | 205 | 195 | 650 | in 3 in. { 20 | 4.391 |
| 97 | 98 | 95 1/2 | 160 | 153 3/4 | 146 1/4 | 490 | in 3 in. { 25 | 5.855 |
| 79 | 80 | 78 | 100 | 102 1/2 | 97 1/2 | 330 | in 3 in. { 30 | 8.782 |

"The wire shall be capable of being wrapped in six turns around wire of its own diameter, unwrapped and again wrapped in six turns around wire of its own diameter in the same direction as the first wrapping, without breaking; and shall be also capable of bearing the number of twists set down in the table, without breaking.

"The twist-test will be made as follows: The wire will be gripped by two vises, one of which will be made to revolve at a speed not exceeding one revolution per second. The twists thus given to the wire will be reckoned by means of an ink mark which forms a spiral on the wire during torsion, the full number of twists to be visible between the vises."

According to the above table, the mile-ohm of copper required is 878 pounds. This corresponds to a conductivity of 96.6 per cent., taking the value of the mile-ohm of 100 per cent. copper as 859.

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## HARD-DRAWN COPPER WIRE.—(*Continued.*)

### Telephone specifications.

| Numbers. | Diameters in mils. | | | Weights per mile. | | | Breaking weights. | | | Weights of coils. | | Conductivity. | | Twists in six inches. | Per cent. elongation in five feet. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Required. | Maximum. | Minimum. | Required. | Maximum. | Minimum. | Actual required. | Actual minimum. | Per square inch. | Maximum. | Minimum. | Required. | Minimum. | | |
| 8 B. W. G..... | 165. | 166. | 164. | 436.4 | 441.7 | 431.1 | 1 328 | 1 301 | 62 100 | 218 | 152 | 97 | 96 | 30 | 1.14 |
| 12 N. B. S. G.. | 104. | 104.9 | 103.1 | 173.4 | 176.4 | 170.4 | 549 | 538 | 64 600 | 219 | 151 | 97 | 96 | 40 | 1. |
| 10 B. & S. G... | 101.9 | 102.8 | 101. | 165. | 168. | 162. | 540 | 519 | 64 800 | 218 | 152 | 97 | 96 | 40 | .99 |
| 12 B. & S. G... | 80. | 81.2 | 79.3 | 102.6 | 105.7 | 100.8 | 334 | 327 | 66 500 | 72 | 52 | 97 | 96 | 44 | .94 |
| 14 B. & S. G... | 64. | 65. | 63. | 65. | 67.5 | 63. | 220 | 212 | 68 200 | ..... | ..... | 97 | 96 | 47 | .91 |

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## TENSILE STRENGTH OF COPPER WIRE.

| Numbers, B. & S. G. | Breaking weight. Pounds. | | Numbers, B. & S. G. | Breaking weight. Pounds. | |
|---|---|---|---|---|---|
| | Hard-drawn. | Annealed. | | Hard-drawn. | Annealed. |
| 0 000 | 8 310 | 5 650 | 9 | 617 | 349 |
| 000 | 6 580 | 4 480 | 10 | 489 | 277 |
| 00 | 5 226 | 3 553 | 11 | 388 | 219 |
| 0 | 4 558 | 2 818 | 12 | 307 | 174 |
| 1 | 3 746 | 2 234 | 13 | 244 | 138 |
| 2 | 3 127 | 1 772 | 14 | 193 | 109 |
| 3 | 2 480 | 1 405 | 15 | 153 | 87 |
| 4 | 1 967 | 1 114 | 16 | 133 | 69 |
| 5 | 1 559 | 883 | 17 | 97 | 55 |
| 6 | 1 237 | 700 | 18 | 77 | 43 |
| 7 | 980 | 555 | 19 | 61 | 34 |
| 8 | 778 | 440 | 20 | 48 | 27 |

The strength of soft copper wire varies from 32 000 to 36 000 pounds per square inch, and of hard copper wire from 45 000 to 68 000 pounds per square inch, according to the degree of hardness.

The above table is calculated for 34 000 pounds for soft wire and 60 000 pounds for hard wire, except for some of the larger sizes, where the breaking weight per square inch is taken at 50 000 pounds for 0 000, 000 and 00, 55 000 for 0, and 57 000 pounds for 1.

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## BI-METALLIC WIRE.

| Numbers, B. & S. G. | Diameters in mils. | Weights per mile. Pounds. | Breaking weight. Pounds. |
|---|---|---|---|
| 0 000 | 460 | 3 200 | 10 500 |
| 000 | 410 | 2 537 | 8 600 |
| 00 | 365 | 2 022 | 7 000 |
| 0 | 325 | 1 620 | 5 700 |
| 1 | 289 | 1 264 | 4 600 |
| 2 | 258 | 1 003 | 3 800 |
| 3 | 229 | 797 | 3 200 |
| 4 | 204 | 629 | 2 600 |
| 5 | 182 | 490 | 1 790 |
| 6 | 162 | 398 | 1 500 |
| 7 | 144 | 314 | 1 210 |
| 8 | 128 | 246 | 1 020 |
| 9 | 114 | 208 | 850 |
| 10 | 102 | 157 | 660 |
| 11 | 91 | 127 | 520 |
| 12 | 81 | 100 | 410 |
| 14 | 64 | 63 | 260 |
| 16 | 51 | 40 | 160 |
| 18 | 40 | 25 | 100 |

This wire consists of a steel center with a cover of copper. Its conductivity is about 65 per cent. of that of pure copper. The percentage of copper and steel may vary a trifle, hence the strength and weight must be approximate.

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## STRANDS OF COPPER WIRE.

COPPER WIRES are laid up into concentric strands or into ropes of seven strands. A rope of seven strands each composed of seven wires, is called a seven by seven rope, and is usually written 7x7. The number of wires that can be made into a strand is limited by the capacity of the stranding machinery. Two hundred wires is the usual limit of a concentric strand, and one hundred and thirty-three wires of a rope.

In a strand of circular milage, C. M., composed of n wires of diameter d, with a weight per 1 000 feet w, then we have

$$C.\ M. = d^2 \times n.$$

$$n = \frac{C.\ M.}{d^2}$$

$$d = \sqrt{\frac{C.\ M.}{n}}$$

$$w = .00305 \times C.\ M.$$

The weights of strands are calculated about one per cent. heavier than a solid wire of the same circular milage, while the resistance is calculated for the solid wire.

In specifying how a strand shall be made, the number of wires to be used or the diameter of each wire may be given. In the first case the wire usually has to be specially drawn, and this will delay an order, especially a small order, unduly. It is, therefore, better to specify the size wires B. &. S. G., of which the strand is to be made.

The diameter of a strand may be calculated by multiplying the diameter of one wire by the factors given in the table at the bottom of the opposite page, according to the number of wires composing the strand.

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# STRANDS OF COPPER WIRE.

## Diameters and properties.

| Numbers, B. & S. G. | Circular mils. | Diameters. | | Weights. | | Resistances at 75° F. per 1 000 ft. |
|---|---|---|---|---|---|---|
| | | Decimal parts of inch. | Nearest 32d. | 1 000 feet. | Mile. | |
| ..... | 1 000 000 | 1.152 | 1 3/32 | 3 050 | 16 104 | .010 51 |
| ..... | 950 000 | 1.125 | 1 1/8 | 2 898 | 15 299 | .011 06 |
| ..... | 900 000 | 1.092 | 1 3/32 | 2 745 | 14 494 | .011 67 |
| ..... | 850 000 | 1.062 | 1 1/16 | 2 593 | 13 688 | .012 36 |
| ..... | 800 000 | 1.035 | 1 1/32 | 2 440 | 12 883 | .013 13 |
| ..... | 750 000 | .999 | 1 | 2 288 | 12 078 | .014 01 |
| ..... | 700 000 | .963 | 31/32 | 2 135 | 11 273 | .015 01 |
| ..... | 650 000 | .927 | 15/16 | 1 983 | 10 468 | .016 17 |
| ..... | 600 000 | .891 | 29/32 | 1 830 | 9 662 | .017 51 |
| ..... | 550 000 | .855 | 7/8 | 1 678 | 8 857 | .019 1 |
| ..... | 500 000 | .819 | 13/16 | 1 525 | 8 052 | .021 01 |
| ..... | 450 000 | .770 | 25/32 | 1 373 | 7 247 | .023 35 |
| ..... | 400 000 | .728 | 3/4 | 1 220 | 6 442 | .026 27 |
| ..... | 350 000 | .679 | 11/16 | 1 068 | 5 636 | .030 02 |
| ..... | 300 000 | .630 | 5/8 | 915 | 4 831 | .035 02 |
| | 250 000 | .590 | 19/32 | 762 | 4 026 | .042 03 |
| 0 000 | 211 600 | .530 | 17/32 | 645 | 3 405 | .049 66 |
| 000 | 168 100 | .470 | 15/32 | 513 | 2 709 | .062 51 |
| 00 | 133 225 | .420 | 7/16 | 406 | 2 144 | .078 87 |
| 0 | 105 625 | .375 | 3/8 | 322 | 1 700 | .099 48 |
| 1 | 83 521 | .330 | 11/32 | 255 | 1 346 | .125 8 |
| 2 | 66 564 | 291 | 9/32 | 203 | 1 072 | .157 9 |
| 3 | 52 441 | .261 | 1/4 | 160 | 845 | .200 4 |
| 4 | 41 616 | .231 | 1/4 | 127 | 671 | .252 5 |

| Numbers of wires. | Factors. | Numbers of wires. | Factors. |
|---|---|---|---|
| 3 | 2¼ | 75 | 10¼ |
| 7 | 3 | 91 | 11 |
| 12 | 4¼ | 108 | 12¼ |
| 19 | 5 | 127 | 13 |
| 27 | 6¼ | 147 | 14¼ |
| 37 | 7 | 169 | 15 |
| 48 | 8¼ | 192 | 16¼ |
| 61 | 9 | 217 | 17 |
| 7x7 | 9 | ..... | ..... |
| 7x19 | 15 | ..... | ..... |

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# DIAMETERS OF WIRES IN STRANDS.

| Circular mils. | Numbers of wires. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 7 | 12 | 19 | 27 | 37 | 48 | 61 | 75 | 91 | 108 | 127 | 147 | 169 | 192 | 217 | 7x7 | 7x19 |
| | Diameter of each wire. | | | | | | | | | | | | | | | | | | |
| 1 000 000 | 1 000. | 377. | 288.7 | 229.4 | 192.5 | 164.4 | 144.3 | 128. | 115.5 | 104.8 | 96.2 | 88.7 | 82.5 | 76.9 | 72.2 | 67.8 | 142.9 | 86.7 |
| 950 000 | 974.6 | 368.4 | 281.4 | 223.6 | 187.6 | 160.2 | 140.7 | 124.7 | 112.6 | 102.1 | 93.8 | 86.4 | 80.4 | 74.9 | 70.3 | 66.1 | 139.2 | 84.5 |
| 900 000 | 948.6 | 358.5 | 273.9 | 217.6 | 182.6 | 155.9 | 136.9 | 121.4 | 109.5 | 99.5 | 91.3 | 84.1 | 78.3 | 72.9 | 68.5 | 64.4 | 135.5 | 82.2 |
| 850 000 | 921.9 | 348.4 | 266.1 | 211.5 | 177.4 | 151.5 | 133.1 | 118. | 106.5 | 96.6 | 88.7 | 81.8 | 76. | 70.9 | 66.5 | 62.5 | 131.7 | 79.9 |
| 800 000 | 894.4 | 338. | 258.2 | 205. | 172.1 | 147. | 129.1 | 114.5 | 103.3 | 93.7 | 86.1 | 79.3 | 73.8 | 68.7 | 64.5 | 60.7 | 127.8 | 77.5 |
| 750 000 | 866. | 327.3 | 250. | 198.6 | 166.7 | 142.3 | 125. | 110.8 | 100. | 90.7 | 83.3 | 76.8 | 71.4 | 66.6 | 62.5 | 58.8 | 123.7 | 75. |
| 700 000 | 836.6 | 316.3 | 241.5 | 191.9 | 161. | 137.5 | 120.8 | 107.1 | 96.6 | 87.7 | 80.5 | 74.2 | 69. | 64.3 | 60.4 | 56.7 | 119.5 | 72.5 |
| 650 000 | 806.2 | 304.7 | 232.7 | 184.9 | 155.2 | 132.5 | 116.4 | 103.2 | 93.1 | 84.5 | 77.6 | 71.5 | 66.5 | 62. | 58.2 | 54.7 | 115.2 | 69.9 |
| 600 000 | 774.6 | 292.7 | 223.6 | 177.6 | 149.1 | 127.3 | 111.8 | 99.1 | 89.4 | 81.2 | 74.5 | 68.7 | 63.9 | 59.5 | 55.9 | 52.5 | 110.7 | 67.1 |
| 550 000 | 741.6 | 280.3 | 214.1 | 170.1 | 142.7 | 121.9 | 107. | 94.9 | 85.6 | 77.7 | 71.4 | 65.8 | 61.2 | 57.1 | 53.5 | 50.3 | 106. | 64.2 |
| 500 000 | 707.1 | 267.2 | 204.1 | 162.2 | 136.1 | 116.2 | 102.1 | 90.5 | 81.7 | 74.1 | 68. | 62.7 | 58.3 | 54.3 | 51. | 48. | 101. | 61.3 |
| 450 000 | 670.8 | 253.5 | 193.7 | 153.8 | 129.1 | 110.3 | 96.8 | 85.8 | 77.5 | 70.3 | 64.6 | 59.5 | 55.3 | 51.6 | 48.4 | 45.5 | 95 8 | 58.1 |
| 400 000 | 632.4 | 239. | 182.6 | 145. | 121.7 | 103.9 | 91.3 | 80.9 | 73. | 66.3 | 60.9 | 56.1 | 52.2 | 48.6 | 45.6 | 42.9 | 90.4 | 54.8 |
| 350 000 | 591.6 | 223.6 | 170.8 | 135.7 | 113.9 | 97.2 | 85.4 | 75.7 | 68.3 | 62. | 56.9 | 52.6 | 48.8 | 45.5 | 42.7 | 40.1 | 84.5 | 51.2 |
| 300 000 | 547.7 | 207. | 158.1 | 125.6 | 105.4 | 90. | 79.1 | 70.1 | 63.2 | 57.4 | 52.7 | 48.6 | 45.2 | 42.1 | 39.5 | 37.1 | 78.3 | 47.4 |
| 250 000 | 500. | 189. | 144.3 | 114.7 | 96.2 | 82.1 | 72.2 | 64. | 57.7 | 52.4 | 48.1 | 44.3 | 41.2 | 38.4 | 36.1 | 33.9 | 71.4 | 43.3 |

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## DIAMETERS OF WIRES IN STRANDS.—(*Continued.*)

| Numbers, B. & S. G. | Numbers of wires. | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 7 | 12 | 19 | 27 | 37 | 48 | 61 | 75 | 91 | 108 | 127 | 147 | 169 | 192 | 217 | 7x7 | 7x19 |
| | Diameter of each wire. | | | | | | | | | | | | | | | | | |
| 0 000 | 265.6 | 178.9 | 132.8 | 105.5 | 88.5 | 75.6 | 67.9 | 58.9 | 53.1 | 48.2 | 44.3 | 40.8 | 37.9 | 35.4 | 33.2 | 31.2 | 65.7 | 39.9 |
| 000 | 236.7 | 155. | 118.3 | 94.1 | 78.9 | 67.4 | 59.2 | 52.5 | 47.3 | 43. | 39.5 | 36.4 | 33.8 | 31.5 | 29.6 | 27.8 | 58.6 | 35.6 |
| 00 | 210.7 | 138. | 105.4 | 83.7 | 70.3 | 60. | 52.7 | 46.7 | 42.2 | 38.3 | 35.1 | 32.4 | 30.1 | 28.1 | 26.3 | 24.8 | 52.1 | 31.7 |
| 0 | 187.7 | 122.8 | 93.8 | 74.6 | 62.6 | 53.4 | 46.9 | 41.6 | 37.5 | 34.1 | 31.3 | 28.8 | 26.8 | 25. | 23.5 | 22.1 | 46.4 | 28.2 |
| 1 | 166.9 | 109.2 | 83.4 | 66.3 | 55.6 | 47.5 | 41.7 | 37. | 33.4 | 30.3 | 27.8 | 25.6 | 23.8 | 22.2 | 20.9 | 19.6 | 41.3 | 25.1 |
| 2 | 149. | 97.5 | 74.5 | 59.2 | 49.7 | 42.4 | 37.2 | 33. | 29.8 | 27.1 | 24.8 | 22.9 | 21.3 | 19.9 | 18.6 | 17.5 | 36.9 | 22.4 |
| 3 | 132.2 | 86.6 | 66.1 | 52.5 | 44.1 | 37.7 | 33.1 | 29.3 | 26.5 | 24. | 22. | 20.3 | 18.9 | 17.6 | 16.5 | 15.6 | 32.7 | 19.9 |
| 4 | 117.8 | 77.1 | 58.9 | 46.8 | 39.3 | 33.5 | 29.5 | 26.1 | 23.6 | 21.4 | 19.6 | 18.1 | 16.8 | 15.7 | 14.7 | 13.9 | 29.1 | 17.7 |
| 5 | 105.1 | 68.8 | 52.5 | 41.8 | 35. | 29.9 | 26.3 | 23.3 | 21. | 19.1 | 17.5 | 16.2 | 15. | 14. | 13.1 | 12.1 | 26. | 15.8 |
| 6 | 93.5 | 61.2 | 46.8 | 37.2 | 31.2 | 26.6 | 23.4 | 20.7 | 18.7 | 17. | 15.6 | 14.4 | 13.4 | 12.5 | 11.7 | 11. | 23.1 | 14.1 |
| 8 | 73.9 | 48.4 | 37. | 29.4 | 24.6 | 21.1 | 18.5 | 16.4 | 14.8 | 13.4 | 12.3 | 11.4 | 10.6 | 9.8 | 9.2 | 8.7 | 18.3 | 11.1 |
| 10 | 58.9 | 38.6 | 29.4 | 23.4 | 19.6 | 16.8 | 14.7 | 13.1 | 11.8 | 10.7 | 9.8 | 9.1 | 8.4 | 7.8 | 7.4 | 6.9 | 14.6 | 8.8 |
| 12 | 46.8 | 30.6 | 23.4 | 18.6 | 15.6 | 13.3 | 11.7 | 10.4 | 9.4 | 8.5 | 7.8 | 7 2 | 6.7 | 6.2 | 5.8 | 5.5 | 11.6 | 7. |
| 14 | 37. | 24.2 | 18.5 | 14.7 | 12.3 | 10.5 | 9.2 | 8.2 | 7.4 | 6.7 | 6.2 | 5.7 | 5.3 | 4.9 | 4.6 | 4.3 | 9.1 | 5.6 |
| 16 | 29.4 | 19.3 | 14.7 | 11.7 | 9.8 | 8.4 | 7.4 | 6.5 | 5.9 | 5.3 | 4.9 | 4.5 | 4.2 | 3.9 | 3.7 | 3.5 | 7.3 | 4.4 |
| 18 | 23.1 | 15.1 | 11.6 | 9 2 | 7.7 | 6.6 | 5.8 | 5.1 | 4.6 | 4.2 | 3.8 | 3.5 | 3.3 | 3.1 | 2.8 | 2.7 | 5.7 | 3.5 |
| 20 | 18.5 | 12.1 | 9.2 | 7.3 | 6.2 | 5.3 | 4.6 | 4.1 | 3.7 | 3.4 | 3.1 | 2.8 | 2.6 | 2.4 | 2.3 | 2.2 | 4.6 | 2.8 |

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## NUMBERS OF WIRES IN STRANDS.

| Circular mils. | Numbers, Brown & Sharpe gauge. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 25 | 28 | 30 | 12 N. B. S. G. |
| | Number of wires in strands. | | | | | | | | | | | | | | | | |
| 1 000 000 | 61. | 96.1 | 120.8 | 152.4 | 192.9 | 244.1 | 307.8 | 384.5 | 498.8 | 625. | 771.6 | 976.6 | 1 562. | 3 121. | 6 299. | 10 000. | 92.5 |
| 950 000 | 58. | 91.3 | 114.8 | 144.8 | 183.2 | 231.9 | 292.4 | 365.3 | 469.1 | 593.8 | 733. | 927.8 | 1 484. | 2 965. | 5 984. | 9 500. | 87.9 |
| 900 000 | 54.9 | 86.5 | 108.7 | 137.2 | 173.6 | 219.7 | 277. | 346.1 | 444.5 | 562.5 | 694.4 | 878.9 | 1 406. | 2 809. | 5 669. | 9 000. | 83.8 |
| 850 000 | 51.9 | 81.7 | 102.7 | 129.5 | 164. | 207.5 | 261.6 | 326.8 | 419.8 | 531.3 | 655.9 | 830.1 | 1 328. | 2 653. | 5 354. | 8 500. | 76. |
| 800 000 | 48.8 | 76.9 | 96.6 | 121.9 | 154.3 | 195.3 | 246.2 | 307.6 | 395.1 | 500. | 617.3 | 781.3 | 1 250. | 2 497. | 5 039. | 8 000. | 74. |
| 750 000 | 45.8 | 72.1 | 90.6 | 114.3 | 144.7 | 183.1 | 230.8 | 288.4 | 370.4 | 468.8 | 578.7 | 732.4 | 1 172. | 2 341. | 4 724. | 7 500. | 69.4 |
| 700 000 | 42.7 | 67.3 | 84.6 | 106.7 | 135. | 170.9 | 215.5 | 269.2 | 345.7 | 437.5 | 540.1 | 683.6 | 1 094. | 2 185. | 4 409. | 7 000. | 64.8 |
| 650 000 | 39.7 | 62.5 | 78.5 | 99.1 | 125.4 | 158.7 | 200.1 | 249.9 | 321. | 406.3 | 501.6 | 634.8 | 1 015. | 2 029. | 4 094. | 6 500. | 60.1 |
| 600 000 | 36 6 | 57.7 | 72.5 | 91.4 | 115.7 | 146.5 | 184.7 | 230.7 | 296.3 | 375. | 463. | 585.9 | 937.4 | 1 873. | 3 779. | 6 000. | 55.5 |
| 550 000 | 33.6 | 52.9 | 66.4 | 83.8 | 106.1 | 134.3 | 169.3 | 211.5 | 271.6 | 343.8 | 424.4 | 537.1 | 859.3 | 1 717. | 3 464. | 5 500. | 50.9 |
| 500 000 | 30.5 | 48.1 | 60.4 | 76.2 | 96.5 | 122.1 | 153.9 | 192.3 | 246.9 | 312.5 | 385.8 | 488.3 | 781.1 | 1 561. | 3 149. | 5 000. | 46.3 |
| 450 000 | 27.5 | 43.2 | 54.4 | 68.6 | 86.8 | 109.8 | 138.5 | 173. | 222.2 | 281.3 | 347.2 | 439.5 | 702.9 | 1 405. | 2 835. | 4 500. | 41.6 |
| 400 000 | 24.4 | 38.4 | 48.3 | 61. | 77.2 | 97.6 | 123.1 | 153.8 | 197.5 | 250. | 308.6 | 390.6 | 624.9 | 1 248. | 2 520. | 4 000. | 37. |
| 350 000 | 21.4 | 33.6 | 42.3 | 53.3 | 67.5 | 85.4 | 107.7 | 134.6 | 172.8 | 218.8 | 270.1 | 341.8 | 546.8 | 1 092. | 2 205. | 3 500. | 32.4 |
| 300 000 | 18.3 | 28.8 | 36.2 | 45.7 | 57.9 | 73.2 | 92.3 | 115.4 | 148.2 | 187.5 | 231.5 | 293. | 468.7 | 936.3 | 1 890. | 3 000. | 27.8 |
| 250 000 | 15.3 | 24. | 30.2 | 38.1 | 48.2 | 61. | 77. | 96.1 | 123.5 | 156.3 | 192.9 | 244.2 | 390.6 | 780.3 | 1 575. | 2 500. | 23.1 |

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## NUMBERS OF WIRES IN STRANDS.—(*Continued.*)

| Numbers, B. & S. G. | Numbers, Brown & Sharpe gauge. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 25 | 28 | 30 |
| | Number of wires in strands. | | | | | | | | | | | | | | | |
| 0 000 | 12.8 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 81.9 | 103.3 | 130.3 | 164.3 | 207.1 | 329.4 | 660.4 | 1 324. | 2 105. |
| 000 | 10.2 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 81.9 | 103.3 | 130.3 | 164.3 | 261.2 | 523.7 | 1 050. | 1 670. |
| 00 | 8.1 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 81.9 | 103.3 | 130.3 | 207.1 | 415.3 | 832.7 | 1 324. |
| 0 | 6.4 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 81.9 | 103.3 | 164.3 | 329.4 | 660.4 | 1 050. |
| 1 | 5.1 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 81.9 | 130.3 | 261.2 | 523 7 | 832.7 |
| 2 | 4. | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 65. | 103.3 | 207.1 | 415.3 | 660.4 |
| 3 | 3.2 | 5.1 | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 51.5 | 81.9 | 164.3 | 329.4 | 523.7 |
| 4 | 2.5 | 4. | 5.1 | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 40.9 | 65. | 130.3 | 261.2 | 415.3 |
| 5 | 2. | 3.2 | 4. | 5.1 | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 32.3 | 51.5 | 103.3 | 207.1 | 329.4 |
| 6 | 1.6 | 2.5 | 3.2 | 4. | 5.1 | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 20.4 | 25.7 | 40.9 | 81.9 | 164.3 | 261.2 |
| 8 | 1. | 1.6 | 2. | 2.5 | 3.2 | 4. | 5.1 | 6.4 | 8.1 | 10.2 | 12.8 | 16.2 | 25.7 | 51.5 | 103.3 | 164.3 |
| 10 | ..... | 1. | 1.3 | 1.6 | 2. | 2.5 | 3.2 | 4. | 5.1 | 6.4 | 8.1 | 10.2 | 16.2 | 32.3 | 65. | 103.3 |
| 12 | ..... | ..... | ..... | 1. | 1.3 | 1.6 | 2. | 2.5 | 3.2 | 4. | 5.1 | 6.4 | 10.2 | 20.4 | 40.9 | 65. |
| 14 | ..... | ..... | ..... | ..... | ..... | 1. | 1.3 | 1.6 | 2. | 2.5 | 3.2 | 4. | 6.4 | 12.8 | 25.7 | 40.9 |
| 16 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1. | 1.3 | 1.6 | 2. | 2.5 | 4. | 8.1 | 16.2 | 25.7 |
| 18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1. | 1.3 | 1.6 | 2.5 | 5.1 | 10.2 | 16.2 |
| 20 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1. | 1.6 | 3.2 | 6.4 | 10.2 |

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# IRON WIRE.

IN COMPARING tables of the weights of Galvanized Iron Wire it was found that the weights of the various sizes were not consistent with each other in the same table, and that no two tables seemed to agree in regard to the specific gravity of the material.

This table is calculated from the formula, weight per mile $= D^2 \times .013\,9$, which seems to be the most likely value for galvanized iron wire. This corresponds with a specific gravity of 7.73, and a weight per cubic foot of 483 pounds.

Steel wire is slightly heavier, and it is probable the constant in the above formula should be .014 for galvanized steel wire.

The following average values of the mile-ohm were used in calculating the resistance per mile at 68° F., the International ohm being the unit:

| Kind of material. | Minimum. | Maximum. | Average. |
|---|---|---|---|
| E. B. B., | 4 500 | 4 800 | 4 700 |
| B. B., | 5 300 | 6 000 | 5 500 |
| Steel, | 6 000 | 7 000 | 6 500 |

The breaking weight of any wire equals its weight per mile multiplied by 3 for E. B. B., 3.3 for B. B., or 3.7 for steel, all annealed and galvanized. This corresponds to 53 100 pounds, 58 410 pounds, and 65 490 pounds per square inch, respectively.

The strength of steel wire varies from 50 000 pounds per square inch to over 300 000 pounds, according to the kind of material and its treatment.

By taking 100 000 pounds per square inch as the breaking strain of steel wire, the breaking strain of any other wire may easily be computed from the table. For a wire of 80 000 pounds per square inch breaking strain, take eight-tenths of the tabulated breaking strain for that size wire at 100 000 pounds per square inch given in the table.

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## GALVANIZED IRON WIRE.

| Numbers, B. W. G. | Diameters in mils. | Weights. Pounds. | | Breaking weights. Pounds. | | Resistance per mile in ohms. | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 000 feet. | One mile. | Iron. | Steel. | E. B. B. | B. B. | Steel. |
| 0 | 340 | 304 | 1 607 | 4 821 | 9 079 | 2.93 | 3.42 | 4.05 |
| 1 | 300 | 237 | 1 251 | 3 753 | 7 068 | 3.76 | 4.4 | 5.2 |
| 2 | 284 | 212 | 1 121 | 3 363 | 6 335 | 4.19 | 4.91 | 5.8 |
| 3 | 259 | 177 | 932 | 2 796 | 5 268 | 5.04 | 5.9 | 6.97 |
| 4 | 238 | 149 | 787 | 2 361 | 4 449 | 5.97 | 6.99 | 8.26 |
| 5 | 220 | 127 | 673 | 2 019 | 3 801 | 6.99 | 8.18 | 9.66 |
| 6 | 203 | 109 | 573 | 1 719 | 3 237 | 8.21 | 9.6 | 11.35 |
| 7 | 180 | 85 | 450 | 1 350 | 2 545 | 10.44 | 12.21 | 14.43 |
| 8 | 165 | 72 | 378 | 1 134 | 2 138 | 12.42 | 14.53 | 17.18 |
| 9 | 148 | 58 | 305 | 915 | 1 720 | 15.44 | 18.06 | 21.35 |
| 10 | 134 | 47 | 250 | 750 | 1 410 | 18.83 | 22.04 | 26.04 |
| 11 | 120 | 38 | 200 | 600 | 1 131 | 23.48 | 27.48 | 32.47 |
| 12 | 109 | 31 | 165 | 495 | 933 | 28.46 | 33.3 | 39.36 |
| 13 | 95 | 24 | 125 | 375 | 709 | 37.47 | 43.85 | 51.82 |
| 14 | 83 | 18 | 96 | 288 | 541 | 49.08 | 57.44 | 67.88 |
| 15 | 72 | 13.7 | 72 | 216 | 407 | 65.23 | 76.33 | 90.21 |
| 16 | 65 | 11.1 | 59 | 177 | 332 | 80.03 | 93.66 | 110.7 |
| 17 | 58 | 8.9 | 47 | 141 | 264 | 100.5 | 120.4 | 139. |
| 18 | 49 | 6.3 | 33 | 99 | 189 | 140.8 | 164.8 | 194.8 |

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## GALVANIZED IRON TELEGRAPH WIRE.

**Western Union Telegraph company's specifications.**
(Condensed).

"1. The wire to be soft and pliable, and capable of elongating 15 per cent. without breaking, after being galvanized.

"2. Great tensile strength is not required, but the wire must not break under a less strain than two and one-half times its weight in pounds per mile.

"3. Tests for ductility will be made as follows: The piece of wire will be gripped by two vises, 6 inches apart, and twisted. The full number of twists must be distinctly visible between the vises on the 6-inch piece. The number of twists in a piece of 6 inches in length not to be under 15.

"4. The weight per mile for the different gauge wires to be: for No. 4, 730 lbs.; No. 6, 540 lbs.; No. 8, 380 lbs.; No. 9, 320 lbs.; No. 10, 250 lbs., or, as near these figures as practicable.

"5. The electrical resistance of the wire in ohms per mile, at a temperature of 68° Fahrenheit, must not exceed the quotient arising from the dividing the constant number 4 800 by the weight of the wire in pounds per mile. The coëfficient .003 will be allowed for each degree Fahrenheit in reducing to standard temperature.

"6. The wire must be well galvanized, and capable of standing the following tests: The wire will be plunged into a saturated solution of sulphate of copper, and permitted to remain one minute, and then wiped clean. This process will be performed four times. If the wire appears black after the fourth immersion, it shows that the zinc has not been all removed, and that the galvanizing is well done; but if it has a copper color, the iron is exposed, showing that the zinc is too thin."

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## GALVANIZED IRON TELEGRAPH WIRE.

**British Post-office specifications.**

| Diameters in mils. | | | Weights per mile. Pounds. | | | Strength and ductility. | | | | | | Resistance per mile of standard size at 60° F. International ohms. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Required. | Maximum. | Minimum. | Required. | Maximum. | Minimum. | Minimum breaking weight. Pounds. | Twists in six inches. | Breaking weight. Not less than | Twists in six inches. | Breaking weight. Not less than | Twists in six inches. | |
| 242 | 247 | 237 | 800 | 833 | 767 | 2 480 | 15 | 2 550 | 14 | 2 620 | 13 | 6.66 |
| 209 | 214 | 204 | 600 | 629 | 571 | 1 860 | 17 | 1 910 | 16 | 1 960 | 15 | 8.88 |
| 181 | 186 | 176 | 450 | 477 | 424 | 1 390 | 19 | 1 425 | 18 | 1 460 | 17 | 11.84 |
| 171 | 176 | 166 | 400 | 424 | 377 | 1 240 | 21 | 1 270 | 20 | 1 300 | 19 | 13.32 |
| 121 | 125 | 118 | 200 | 213 | 190 | 620 | 30 | 638 | 28 | 655 | 26 | 26.61 |

"The wire shall be well galvanized with zinc spelter, and this will be tested by an officer appointed by the Postmaster-General to inspect and test the wire, and hereinafter called the Inspecting Officer, taking samples from any piece or pieces and plunging them into a saturated solution of sulphate of copper, at 60° F., and allowing them to remain in the solution for one minute, when they are to be withdrawn and wiped clean. The galvanizing shall admit of this process being four times performed with each sample without there being, as there would be if the coating of zinc were too thin, any sign of a reddish deposit of metallic copper on the wire. Samples taken from pieces of the 800-lb. wire shall also bear bending around a bar 2½ inches in diameter without any signs appearing of the zinc cracking or peeling off; the 600-lb. wire shall similarly bear bending around a bar 2¼ inches in diameter; the 450-lb. and 400-lb. wire around a bar 2 inches in diameter; and the 200-lb. wire around a bar 1½ inches in diameter."

The mile-ohm is 5 323.

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## GALVANIZED SUPPORTING STRANDS.

What weight per foot will a half-inch ordinary strand support if the strain is one-half the breaking weight, the span 120 feet, and the deflection .01 of the span or 1.2 feet?

One-half the breaking weight of a half-inch ordinary galvanized strand is 4 160 pounds. The value of S for above span and deflection, table page 50, is 1 500.2. Dividing 4 160 by 1 500.2 we find the total weight per foot to be 2.773 pounds. Deducting from this the weight per foot of the half-inch galvanized strand we have 2.263 pounds as the weight per foot of cable that this strand will support. While it is true that a factor of safety of two in this work is too small, yet the cables help in a great measure to carry their own weight. It is believed that galvanized strands will easily carry the loads indicated on page 39.

---

This strand is composed of seven wires, twisted together into a single strand.

| Diameters in 32ds of an inch. | Weights per 100 feet. Pounds. | Estimated breaking strength. Pounds. | |
|---|---|---|---|
| | | Ordinary. | Special. |
| 16 | 51 | 8 320 | 16 640 |
| 15 | 48 | 7 500 | 15 000 |
| 14 | 37 | 6 000 | 12 000 |
| 12 | 30 | 4 700 | 9 400 |
| 10 | 21 | 3 300 | 6 600 |
| 9 | 18 | 2 600 | 5 200 |
| 8 | 11½ | 1 750 | 3 500 |
| 7 | 8¾ | 1 300 | 2 600 |
| 6 | 6½ | 1 000 | 2 000 |
| 5 | 4½ | 700 | 1 400 |
| 4 | 2¼ | 375 | 750 |
| 3 | 2 | 320 | 640 |

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# SUPPORTING CAPACITY OF GALVANIZED STRANDS.

## Ordinary.

| Diameters of strands in 32ds of an inch. | Spans in feet. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 | 110 | 120 | 125 | 130 | 140 | 150 | 175 | 200 |
| | Weights of 1 000 feet of cable. Pounds. | | | | | | | | |
| 16 | 2 818 | 2 516 | 2 263 | 2 152 | 2 050 | 1 867 | 1 709 | 1 391 | 1 154 |
| 15 | 2 520 | 2 247 | 2 020 | 1 920 | 1 827 | 1 663 | 1 520 | 1 234 | 1 130 |
| 14 | 2 030 | 1 812 | 1 630 | 1 550 | 1 476 | 1 344 | 1 230 | 1 001 | 900 |
| 12 | 1 580 | 1 409 | 1 266 | 1 204 | 1 146 | 1 043 | 953 | 774 | 640 |
| 10 | 1 110 | 899 | 890 | 846 | 805 | 733 | 670 | 544 | 450 |
| 9 | 860 | 765 | 680 | 652 | 620 | 563 | 513 | 414 | 340 |
| 8 | 585 | 521 | 468 | 445 | 423 | 385 | 352 | 285 | 235 |
| 7 | 433 | 385 | 346 | 329 | 313 | 284 | 260 | 210 | 172 |
| 6 | 337 | 300 | 270 | 257 | 245 | 223 | 204 | 165 | 137 |

## Special.

| Diameters of strands in 32ds of an inch. | Spans in feet. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 | 110 | 120 | 125 | 130 | 140 | 150 | 175 | 200 |
| | Weights of 1 000 feet of cable. Pounds. | | | | | | | | |
| 16 | 6 146 | 5 482 | 5 036 | 4 814 | 4 510 | 4 244 | 3 928 | 3 292 | 2 818 |
| 15 | 5 520 | 4 974 | 4 520 | 4 320 | 4 134 | 3 808 | 3 520 | 2 948 | 2 520 |
| 14 | 4 430 | 3 994 | 3 630 | 3 470 | 3 322 | 3 058 | 2 830 | 2 372 | 2 030 |
| 12 | 3 460 | 3 118 | 2 832 | 2 708 | 2 592 | 2 386 | 2 206 | 1 848 | 1 580 |
| 10 | 2 430 | 2 008 | 1 990 | 1 902 | 1 820 | 1 676 | 1 550 | 1 298 | 1 110 |
| 9 | 1 900 | 1 710 | 1 540 | 1 484 | 1 420 | 1 306 | 1 206 | 1 008 | 860 |
| 8 | 1 285 | 1 157 | 1 051 | 1 005 | 961 | 885 | 819 | 685 | 585 |
| 7 | 953 | 857 | 778 | 745 | 712 | 655 | 607 | 507 | 473 |
| 6 | 737 | 663 | 603 | 577 | 553 | 509 | 472 | 393 | 337 |

Dip = .01 of span.
Factor of safety of two.

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# CURRENTS.

## FUSING EFFECTS OF CURRENTS.

**Table giving the diameters of wires of various materials which will be fused by a current of given strength.**

W. H. PREECE, F.R.S.

$$d = \left(\frac{C}{a}\right)^{\frac{3}{2}}$$

| Current in amperes. | Diameters in inches. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Copper, a=10 244. | Aluminum, a=7 586. | Platinum, a=5 172. | German silver, a=5 230. | Platinoid, a=4 750. | Iron, a=3 148. | Tin, a=1 642. | Tin-lead alloy, a=1 318. | Lead, a=1 379. |
| 1 | 0.002 1 | 0.002 6 | 0.003 3 | 0.003 3 | 0.003 5 | 0.004 7 | 0.007 2 | 0.008 3 | 0.008 1 |
| 2 | 0.003 4 | 0.004 1 | 0.005 3 | 0.005 3 | 0.005 6 | 0.007 4 | 0.011 3 | 0.013 2 | 0.012 8 |
| 3 | 0.004 4 | 0.005 4 | 0.007 | 0.006 9 | 0.007 4 | 0.009 7 | 0.014 9 | 0.017 3 | 0.016 8 |
| 4 | 0.005 3 | 0.006 5 | 0.008 4 | 0.008 4 | 0.008 9 | 0.011 7 | 0.018 1 | 0.021 | 0.020 3 |
| 5 | 0.006 2 | 0.007 6 | 0.009 8 | 0.009 7 | 0.010 4 | 0.013 6 | 0.021 | 0.024 3 | 0.023 6 |
| 10 | 0.009 8 | 0.012 | 0.015 5 | 0.015 4 | 0.016 4 | 0.021 6 | 0.033 4 | 0.038 6 | 0.037 5 |
| 15 | 0.012 9 | 0.015 8 | 0.020 3 | 0.020 2 | 0.021 5 | 0.028 3 | 0.043 7 | 0.050 6 | 0.049 1 |
| 20 | 0.015 6 | 0.019 1 | 0.024 6 | 0.024 5 | 0.026 1 | 0.034 3 | 0.052 9 | 0.061 3 | 0.059 5 |
| 25 | 0.018 1 | 0.022 2 | 0.028 6 | 0.028 4 | 0.030 3 | 0.039 8 | 0.061 4 | 0.071 1 | 0.069 |
| 30 | 0.020 5 | 0.025 | 0.032 3 | 0.032 | 0.034 2 | 0.045 | 0.069 4 | 0.080 3 | 0.077 9 |
| 35 | 0.022 7 | 0.027 7 | 0.035 8 | 0.035 6 | 0.037 9 | 0.049 8 | 0.076 9 | 0.089 | 0.086 4 |
| 40 | 0.024 8 | 0.030 3 | 0.039 1 | 0.038 8 | 0.041 4 | 0.054 5 | 0.084 | 0.097 3 | 0.094 4 |
| 45 | 0.026 8 | 0.032 8 | 0.042 3 | 0.042 | 0.044 8 | 0.058 9 | 0.090 9 | 0.105 2 | 0.102 1 |
| 50 | 0.028 8 | 0.035 2 | 0.045 4 | 0.045 | 0.048 | 0.063 2 | 0.097 5 | 0.112 9 | 0.109 5 |
| 60 | 0.032 5 | 0.039 7 | 0.051 3 | 0.050 9 | 0.054 2 | 0.071 4 | 0.110 1 | 0.127 5 | 0.123 7 |
| 70 | 0.036 | 0.044 | 0.056 8 | 0 056 4 | 0.060 1 | 0.079 1 | 0.122 | 0.141 3 | 0.137 1 |
| 80 | 0.039 4 | 0.048 1 | 0.062 1 | 0.061 6 | 0.065 7 | 0.086 4 | 0.133 4 | 0.154 4 | 0.149 9 |
| 90 | 0.042 6 | 0.052 | 0.067 2 | 0.066 7 | 0.071 1 | 0.093 5 | 0.144 3 | 0.167 1 | 0.162 1 |
| 100 | 0.045 7 | 0.055 8 | 0.072 | 0.071 5 | 0.076 2 | 0.100 3 | 0.154 8 | 0.179 2 | 0.173 9 |
| 120 | 0.051 6 | 0.063 | 0.081 4 | 0.080 8 | 0.086 1 | 0.113 3 | 0.174 8 | 0.202 4 | 0.196 4 |
| 140 | 0.057 2 | 0.069 8 | 0.090 2 | 0.089 5 | 0.095 4 | 0.125 5 | 0.193 7 | 0.224 3 | 0.217 6 |
| 160 | 0.062 5 | 0.076 3 | 0.098 6 | 0.097 8 | 0.104 3 | 0.137 2 | 0.211 8 | 0.245 2 | 0.237 9 |
| 180 | 0.067 6 | 0.082 6 | 0.106 6 | 0.105 8 | 0.112 8 | 0.148 4 | 0.229 1 | 0.265 2 | 0.257 3 |
| 200 | 0.072 5 | 0.088 6 | 0.114 4 | 0.113 5 | 0.121 | 0.159 2 | 0.245 7 | 0.284 5 | 0.276 |
| 225 | 0.078 4 | 0.095 8 | 0.123 7 | 0.122 8 | 0.130 9 | 0.172 2 | 0 265 8 | 0.307 7 | 0.298 6 |
| 250 | 0.084 1 | 0.102 8 | 0.132 7 | 0.131 7 | 0.140 4 | 0.184 8 | 0.285 1 | 0 330 1 | 0.320 3 |
| 275 | 0.089 7 | 0.109 5 | 0.141 4 | 0.140 4 | 0.149 7 | 0.196 9 | 0.303 8 | 0.351 8 | 0.341 7 |
| 300 | 0.095 | 0.116 1 | 0.149 8 | 0.148 7 | 0.158 6 | 0.208 6 | 0.322 | 0.372 8 | 0.361 7 |

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## FUSING EFFECTS OF CURRENTS.—(*Continued.*)

**Table showing the amperes required to fuse wires of various sizes and materials.**

| Numbers, N. B. S. G. | Diameter, d. | $d^{\frac{3}{2}}$. | Copper, a=10 244. | Aluminum, a=7 585. | Platinum, a=5 172. | German silver, a=5 230. | Platinoid, a=4 750. | Iron, a=3 148. | Tin, a=1 642. | Tin-lead alloy, a=1 318. | Lead, a=1 379. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 0.08 | 0.022 627 | 231 8 | 171.6 | 117. | 118.3 | 107.5 | 71.22 | 37.15 | 29.82 | 31.2 |
| 16 | 0.064 | 0.016 191 | 165.8 | 122.8 | 83.73 | 84.68 | 76.9 | 50.96 | 26.58 | 21.34 | 22.32 |
| 18 | 0.048 | 0.010 516 | 107.7 | 79.75 | 54.37 | 54.99 | 49.95 | 33.1 | 17.27 | 13.86 | 14.5 |
| 20 | 0.036 | 0.006 831 | 69.97 | 51.18 | 35.33 | 35 72 | 32.44 | 21.5 | 11.22 | 9.002 | 9.419 |
| 22 | 0.028 | 0.004 685 | 48. | 35.53 | 24.23 | 24.5 | 22.25 | 14.75 | 7.692 | 6.175 | 6.461 |
| 24 | 0.022 | 0.003 263 | 33.43 | 24.75 | 16.88 | 17.06 | 15.5 | 10.27 | 5.357 | 4.3 | 4.499 |
| 26 | 0.018 | 0.002 415 | 24.74 | 18.32 | 12.49 | 12.63 | 11.47 | 7.602 | 3.965 | 3.183 | 3.33 |
| 28 | 0.014 8 | 0.001 801 | 18.44 | 13.66 | 9.311 | 9.416 | 8.552 | 5.667 | 2.956 | 2.373 | 2.483 |
| 30 | 0.012 4 | 0.001 381 | 14.15 | 10.47 | 7.142 | 7.222 | 6.559 | 4.347 | 2.267 | 1.82 | 1.904 |
| 32 | 0.010 8 | 0.001 122 | 11.5 | 8.512 | 5.805 | 5.87 | 5.33 | 3.533 | 1.843 | 1.479 | 1.548 |

NOTE.—The size of "cut-outs," or fuses for electric-lighting circuits, can be taken at once from the first table. Pure copper wire makes the best and most reliable cut-out or fuse, and should never be less than one inch in length between the terminals to which it is fixed so as to prevent the cooling effect of the terminals.

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## HEATING EFFECTS OF CURRENTS.

A REPORT read before the Edison Convention, at Niagara Falls, August, 1889, by A. E. Kennelly, gives complete formulæ and tables based on experimental data, showing the heating effects of electric currents. This report was published in the *Electrical World*, beginning with the edition of November 23, 1889.

The tables in this book are taken from curves constructed from data given in the above report.

The table page 43 gives the rules of the various insurance companies, together with one column giving the current whose double would cause a rise of 40° C. This is the safe carrying capacity recommended in Kennelly's report.

The table page 44 gives the diameters of various wires and the current they will carry with a specified rise in temperature. The wires are insulated, and the conditions are similar to those met with in house wiring in mouldings or conduits.

The table page 45 is computed for bare wires suspended indoors, and gives the current carried with the corresponding rise in temperature.

The table page 46 is computed for outdoor wires, not insulated.

In these tables all wires are solid.

Insulation increases the current a wire will carry with a given rise in temperature, because the radiating surface is increased, and for the same reason a strand will carry a larger current than a solid wire.

One square inch of bright copper radiates .003 9 watts per degree Centigrade rise in temperature, and one square inch of blackened copper, .009 watts, under the same conditions. Convection seems to be dependent only on length, and may be taken at .053 watts per foot per degree Centigrade rise.

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## HEATING EFFECTS OF CURRENTS.

**Insurance rules for carrying capacity of wires.**

| Numbers, B. & S. G. | Current, the double of which will cause a rise of 72° F. | National Electric Light association. | National Board of Fire Underwriters. | | Associated Factory Mutual Insurance company. | Phœnix Fire Insurance company and Board of Trade rules of England. |
|---|---|---|---|---|---|---|
| | | | Concealed work. | Open work. | | |
| 0 000 | 174 | 175 | 218 | 312 | 175 | ..... |
| 000 | 146 | 145 | 181 | 262 | 145 | ..... |
| 00 | 123 | 120 | 150 | 220 | 120 | 105 |
| 0 | 103 | 100 | 125 | 185 | 100 | 83 |
| 1 | 88 | 95 | 105 | 156 | 85 | 66 |
| 2 | 73 | 70 | 88 | 131 | 70 | 52 |
| 3 | 61 | 60 | 75 | 110 | 60 | 41 |
| 4 | 52 | 50 | 63 | 92 | 50 | 33 |
| 5 | 43 | 45 | 53 | 77 | 45 | 26 |
| 6 | 36 | 35 | 45 | 65 | 35 | 21 |
| 7 | 31 | 30 | ..... | ..... | 30 | 16 |
| 8 | 26 | 25 | 33 | 46 | 25 | 13 |
| 10 | 18 | 20 | 25 | 32 | 20 | 8 |
| 12 | 13 | 15 | 17 | 23 | 15 | 5 |
| 14 | 9 | 10 | 12 | 16 | 10 | 3 |
| 16 | 6 | 5 | 6 | 8 | 5 | 2 |
| 18 | 5 | ..... | 3 | 5 | 3 | 1 |

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## HEATING EFFECTS OF CURRENTS.—(*Cont.*)

### Carrying capacity of insulated wires in mouldings.

(Kennelly's formula.)

| Amperes. | Rise in temperature in degrees Centigrade. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5° | 10° | 15° | 20° | 30° | 40° | 50° | 60° | 70° |
| | Diameters of wires in mils. | | | | | | | | |
| 300 | ..... | ..... | ..... | ..... | 446 | 411 | 386 | 367 | 354 |
| 280 | ..... | ..... | ..... | ..... | 427 | 393 | 369 | 350 | 338 |
| 260 | ..... | ..... | ..... | 450 | 409 | 375 | 352 | 333 | 321 |
| 240 | ..... | ..... | ..... | 430 | 390 | 356 | 333 | 315 | 304 |
| 220 | ..... | ..... | 436 | 408 | 370 | 337 | 315 | 298 | 285 |
| 200 | ..... | 448 | 414 | 386 | 350 | 317 | 295 | 280 | 268 |
| 190 | ..... | 437 | 403 | 375 | 339 | 308 | 286 | 270 | 258 |
| 180 | ..... | 425 | 391 | 364 | 328 | 298 | 277 | 260 | 249 |
| 170 | ..... | 411 | 378 | 352 | 317 | 287 | 266 | 250 | 239 |
| 160 | ..... | 398 | 364 | 340 | 305 | 276 | 256 | 241 | 229 |
| 150 | 445 | 383 | 351 | 326 | 293 | 265 | 244 | 230 | 218 |
| 140 | 431 | 370 | 338 | 312 | 281 | 253 | 232 | 220 | 206 |
| 130 | 417 | 354 | 322 | 300 | 269 | 240 | 220 | 208 | 195 |
| 120 | 400 | 339 | 308 | 285 | 255 | 228 | 208 | 195 | 182 |
| 110 | 383 | 322 | 292 | 270 | 240 | 214 | 195 | 182 | 170 |
| 100 | 362 | 302 | 276 | 253 | 223 | 200 | 182 | 168 | 158 |
| 90 | 343 | 284 | 259 | 237 | 208 | 185 | 168 | 154 | 143 |
| 80 | 322 | 264 | 240 | 218 | 192 | 169 | 153 | 139 | 130 |
| 70 | 300 | 242 | 220 | 198 | 174 | 152 | 139 | 123 | 116 |
| 60 | 275 | 220 | 195 | 175 | 155 | 135 | 122 | 108 | 101 |
| 50 | 250 | 195 | 175 | 152 | 132 | 118 | 104 | 91 | 86 |
| 40 | 217 | 169 | 144 | 128 | 110 | 95 | 85 | 75 | 70 |
| 30 | 178 | 136 | 115 | 100 | 85 | 73 | 66 | 58 | 54 |
| 20 | 132 | 100 | 71 | 69 | 59 | 50 | 45 | 40 | 37 |
| 10 | 78 | 58 | 42 | 35 | 30 | ..... | ..... | ..... | ..... |

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## HEATING EFFECTS OF CURRENTS.—(*Cont.*)

**Bare copper in still air.**

| Amperes. | Rise in temperature, degrees Centigrade. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10° | | 20° | | 40° | | 80° | |
| | Bright. | Black. | Bright. | Black. | Bright. | Black. | Bright. | Black. |
| | Diameters of wires in mils. | | | | | | | |
| 1 000 | ..... | ..... | ..... | ..... | ..... | 968 | 911 | 750 |
| 950 | ..... | ..... | ..... | ..... | ..... | 930 | 878 | 728 |
| 900 | ..... | ..... | ..... | ..... | ..... | 893 | 844 | 695 |
| 850 | ..... | ..... | ..... | ..... | ..... | 858 | 809 | 666 |
| 800 | ..... | ..... | ..... | ..... | 1 000 | 823 | 771 | 638 |
| 750 | ..... | ..... | ..... | ..... | 950 | 785 | 734 | 610 |
| 700 | ..... | ..... | ..... | 960 | 900 | 748 | 696 | 580 |
| 650 | ..... | ..... | ..... | 910 | 850 | 708 | 660 | 550 |
| 600 | ..... | ..... | ..... | 858 | 800 | 668 | 621 | 518 |
| 575 | ..... | ..... | ..... | 833 | 775 | 648 | 603 | 503 |
| 550 | ..... | 995 | 980 | 808 | 750 | 628 | 583 | 488 |
| 525 | ..... | 978 | 948 | 780 | 725 | 607 | 563 | 461 |
| 500 | ..... | 960 | 913 | 751 | 700 | 584 | 543 | 455 |
| 475 | ..... | 925 | 880 | 723 | 675 | 563 | 523 | 439 |
| 450 | ..... | 895 | 843 | 696 | 648 | 541 | 501 | 421 |
| 425 | ..... | 860 | 808 | 669 | 620 | 520 | 479 | 406 |
| 400 | 1 000 | 820 | 770 | 641 | 592 | 498 | 457 | 387 |
| 375 | 950 | 783 | 731 | 612 | 564 | 475 | 435 | 369 |
| 350 | 900 | 745 | 690 | 581 | 536 | 452 | 413 | 350 |
| 325 | 850 | 708 | 654 | 550 | 506 | 428 | 390 | 331 |
| 300 | 800 | 668 | 615 | 519 | 475 | 403 | 366 | 312 |
| 275 | 750 | 628 | 575 | 487 | 444 | 377 | 341 | 292 |
| 250 | 696 | 586 | 534 | 453 | 412 | 351 | 317 | 272 |
| 225 | 642 | 545 | 494 | 419 | 379 | 323 | 291 | 252 |
| 200 | 586 | 500 | 453 | 384 | 345 | 296 | 265 | 229 |
| 175 | 530 | 454 | 406 | 349 | 310 | 266 | 239 | 208 |
| 150 | 470 | 404 | 360 | 311 | 274 | 226 | 210 | 194 |
| 125 | 408 | 352 | 308 | 270 | 235 | 206 | 182 | 161 |
| 100 | 343 | 300 | 258 | 226 | 195 | 170 | 150 | 135 |
| 90 | 315 | 272 | 237 | 208 | 178 | 158 | 137 | 123 |
| 80 | 286 | 246 | 214 | 196 | 161 | 143 | 124 | 112 |
| 70 | 259 | 220 | 190 | 170 | 143 | 127 | 110 | 100 |
| 60 | 226 | 194 | 167 | 150 | 125 | 112 | 97 | 87 |
| 50 | 191 | 167 | 142 | 130 | 106 | 95 | 82 | 74 |
| 40 | 156 | 140 | 117 | 108 | 86 | 78 | 68 | 61 |
| 30 | 120 | 111 | 90 | 85 | 66 | 60 | 54 | 48 |
| 20 | 82 | 76 | 63 | 60 | 45 | 44 | 40 | 36 |
| 10 | 40 | 38 | 37 | 35 | 30 | 28 | 26 | 24 |

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## HEATING EFFECTS OF CURRENTS.—(*Cont.*)

**Bare copper suspended outdoors.**

| Amperes. | Rise in temperature, degrees Centigrade. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 5° | | 10° | | 20° | | 40° | |
| | Bright. | Black. | Bright. | Black. | Bright. | Black. | Bright. | Black. |
| | Diameters of wires in mils. | | | | | | | |
| 1 000 | ..... | ..... | 962 | 932 | 771 | 745 | 620 | 594 |
| 950 | ..... | ..... | 928 | 897 | 744 | 720 | 595 | 572 |
| 900 | ..... | ..... | 894 | 865 | 715 | 692 | 574 | 552 |
| 850 | ..... | ..... | 868 | 843 | 689 | 665 | 550 | 530 |
| 800 | ..... | ..... | 839 | 810 | 672 | 649 | 537 | 512 |
| 750 | ..... | 975 | 804 | 775 | 643 | 620 | 515 | 495 |
| 700 | 963 | 933 | 767 | 739 | 613 | 591 | 491 | 472 |
| 650 | 916 | 889 | 729 | 703 | 582 | 561 | 467 | 449 |
| 600 | 869 | 837 | 690 | 665 | 554 | 532 | 442 | 426 |
| 575 | 845 | 813 | 671 | 647 | 538 | 517 | 429 | 414 |
| 550 | 820 | 789 | 650 | 627 | 522 | 501 | 417 | 402 |
| 525 | 795 | 764 | 630 | 609 | 506 | 487 | 404 | 389 |
| 500 | 770 | 740 | 610 | 589 | 489 | 470 | 390 | 376 |
| 475 | 745 | 719 | 589 | 569 | 473 | 455 | 377 | 363 |
| 450 | 719 | 693 | 568 | 548 | 453 | 438 | 363 | 350 |
| 425 | 690 | 667 | 546 | 526 | 436 | 422 | 349 | 336 |
| 400 | 661 | 638 | 524 | 504 | 418 | 406 | 334 | 322 |
| 375 | 632 | 610 | 502 | 484 | 399 | 377 | 319 | 309 |
| 350 | 601 | 581 | 478 | 462 | 380 | 360 | 304 | 295 |
| 325 | 571 | 552 | 453 | 439 | 362 | 342 | 289 | 279 |
| 300 | 540 | 522 | 428 | 415 | 342 | 326 | 273 | 264 |
| 275 | 509 | 492 | 404 | 392 | 321 | 309 | 257 | 249 |
| 250 | 477 | 460 | 378 | 367 | 300 | 290 | 240 | 222 |
| 225 | 445 | 430 | 351 | 343 | 280 | 270 | 223 | 215 |
| 200 | 410 | 399 | 324 | 316 | 259 | 250 | 205 | 198 |
| 175 | 373 | 365 | 296 | 289 | 235 | 227 | 186 | 180 |
| 150 | 334 | 329 | 267 | 258 | 211 | 202 | 166 | 161 |
| 125 | 295 | 290 | 235 | 226 | 185 | 177 | 145 | 144 |
| 100 | 254 | 248 | 202 | 193 | 157 | 152 | 123 | 120 |
| 90 | 236 | 230 | 186 | 178 | 145 | 140 | 114 | 111 |
| 80 | 216 | 212 | 171 | 164 | 132 | 128 | 104 | 102 |
| 70 | 198 | 192 | 155 | 150 | 120 | 116 | 94 | 91 |
| 60 | 177 | 170 | 137 | 132 | 107 | 104 | 83 | 80 |
| 50 | 155 | 147 | 119 | 115 | 92 | 87 | 72 | 70 |
| 40 | 130 | 124 | 100 | 96 | 77 | 73 | 62 | 59 |
| 30 | 104 | 100 | 78 | 75 | 61 | 58 | 50 | 45 |
| 20 | 73 | 70 | 54 | 53 | 43 | 40 | 34 | 30 |
| 10 | 40 | 38 | 27 | 26 | 20 | 18 | 16 | 14 |

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# SPANS.

THE formulæ used in calculating these tables of lengths and strains in spans of wire are those of a catenary of small deflection. They are given in Weisbach's Mechanics of Engineering, page 297, (seventh American edition, translated by Eckley B. Coxe, A. M.)

In these tables the horizontal strain at the center of the span is given. The strain at any other point equals the strain at the center plus the weight of a length of the wire equal to the perpendicular distance of that point from the lowest point of the wire in the span. For ordinary spans this is negligible. For any given wire the longest possible span is one where the deflection is about one-third of the span.

The effects of temperature on the strains of wires in spans is at first sight so great as to render the other considerations of little importance. The table, page 53, is calculated on the assumption that the supports of the spans are perfectly rigid under all conditions of strain and that the wire is inelastic. This is never true in practice. The changes in direction in a pole line afford a chance for the strains, due to a shortening of the wire by a fall in temperature, to be taken up by a bending of the supports.

If the elastic limit of hard-drawn copper wire of 60 000 pounds breaking strain be taken at 20 000 pounds, then S will equal 20 000 divided by 3.85, the weight of a piece of copper one foot long and one square inch in section. This makes S equal 5 195. Looking at the table of values of S, page 50, this value for a span of 130 feet comes between a deflection of .003 and .004. In the same way the allowable deflection for any other span of hard-drawn copper could be found or for any other material by substituting the proper terms for the elastic limit and the weight per foot given above.

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The following gives the practice of some of the telegraph and telephone companies in their line construction:

## SPECIFICATIONS FOR STANDARD CONSTRUCTION OF HARD-DRAWN COPPER.

| Temperature in degrees Fahrenheit. | Spans in feet. | | | | | |
|---|---|---|---|---|---|---|
| | 75 | 100 | 115 | 130 | 150 | 200 |
| | Sag in inches. | | | | | |
| −30 | 1 | 2 | 2½ | 3⅜ | 4½ | 8 |
| −10 | 1⅛ | 2⅛ | 3 | 3⅝ | 5 | 9 |
| 10 | 1⅜ | 2⅝ | 3½ | 4⅝ | 5¾ | 10¼ |
| 30 | 1¾ | 3 | 4 | 5⅛ | 6¾ | 12 |
| 60 | 2½ | 4¼ | 5½ | 7 | 9 | 15⅝ |
| 80 | 3⅛ | 5⅜ | 7 | 8⅝ | 11¼ | 18¾ |
| 100 | 4⅛ | 7 | 9 | 11 | 14 | 22¼ |

For spans between 400 and 600 feet, the dip shall be 1-40th of the span.

For spans between 600 and 1 000 feet, the dip shall be 1-30th of the span.

Another company uses 40 poles to the mile, and in the East allows three-inch dip at center of spans. In the West, where the variation of temperature is greater, 10 inches dip is allowed in summer, and 8 inches in the winter. This construction applies to both copper and iron wire, and has been found by actual experience to give satisfactory results.

The following formulæ were used in calculating the tables:

(1) $S \times W =$ horizontal strain on wire at center of span

(2) $$S = \frac{y^2}{2x} + \frac{x}{6}.$$

(3) $$l = y\left[1 + \tfrac{8}{3}\left(\frac{x}{y}\right)^2\right].$$

(4) $$x = 3S - \sqrt{9S^2 - 8y^2}.$$

(5) $$x = \sqrt{\frac{3yl - 3y^2}{2}}$$

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In these formulæ

y = one-half span.
l = one-half length of wire in span.
x = deflection at center in same units as y.
w = weight per foot of wire.

Suppose we have a span of 200 feet of hard-drawn copper wire weighing one pound to 10 feet, and a deflection of two feet or .01 of the span.

(2) $$S = \left(\frac{100}{2}\right)^2 + \frac{2}{3}.$$

$$= 2\,500.33 +.$$

(3) $$l = 100\left[1 + \frac{8}{3}\left(\frac{2}{100}\right)^2\right].$$

$$= 100.026\,6 +.$$

$$2l = 200.053 +.$$

(4) $$x = 7501 - \sqrt{56\,265\,001 - 30\,000.}$$

$$= 2.$$

(5) $$x = \sqrt{\frac{30\,008 - 30\,000}{2.}}$$

$$= 2.$$

In calculating the table, page 53, the deflection of the line was determined at — 10° F. by formula 4, the value of S being 30 000 divided by 3.85 or 7 792. For the other temperatures the length of the wire was calculated from the following formula:

$$\text{Length} = l\,(1 + .000\,009\,8\,t).$$

Here t is the difference in temperature in degrees Fahrenheit.

By formula 5 the deflection corresponding to the new length was found.

The coëfficients of linear expansion for each degree Fahrenheit are as follows:

Copper, .000 009 8.
Iron, .000 006 8.
Lead, .000 016.

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# STRAINS AT CENTERS OF SPANS RESULTING FROM A GIVEN DEFLECTION.

| Spans in feet. | Deflections in decimal parts of spans. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | .001 | .002 | .003 | .004 | .005 | .006 | .007 | .008 | .009 | .010 | .015 |
| | Multipliers. | | | | | | | | | | |
| 10 | 1 250.001 | 625.008 | 416.671 | 312.506 | 250.008 | 208.343 | 178.583 | 156.263 | 138.908 | 125.016 | 83.358 |
| 20 | 2 500.003 | 1 250.006 | 833.343 | 625.013 | 500.016 | 416.686 | 357.166 | 312.526 | 277.807 | 250.033 | 166.716 |
| 30 | 3 750.005 | 1 875.01 | 1 250.015 | 937.52 | 750.025 | 625.03 | 535.749 | 468.79 | 416.711 | 375.05 | 250.075 |
| 40 | 5 000.006 | 2 500.013 | 1 666.686 | 1 250.026 | 1 000.033 | 833.373 | 714.332 | 625.053 | 555.615 | 500.066 | 333.433 |
| 50 | 6 250.008 | 3 125.016 | 2 083.358 | 1 562.533 | 1 250.041 | 1 041.716 | 892.915 | 781.316 | 694.519 | 625.083 | 416.791 |
| 60 | 7 500.01 | 3 750.02 | 2 500.03 | 1 875.04 | 1 500.05 | 1 250.06 | 1 071.498 | 937.58 | 833.423 | 750.1 | 500.15 |
| 70 | 8 750.011 | 4 375.023 | 2 916.701 | 2 187.546 | 1 750.058 | 1 458.403 | 1 250.081 | 1 093.843 | 972.327 | 875.116 | 583.508 |
| 80 | 10 000.013 | 5 000.026 | 3 333.373 | 2 500.053 | 2 000.066 | 1 666.746 | 1 428.664 | 1 250.106 | 1 111.231 | 1 000.133 | 666.866 |
| 90 | 11 250.015 | 5 625.03 | 3 750.045 | 2 812.56 | 2 250.075 | 1 875.09 | 1 607.247 | 1 406.37 | 1 250.135 | 1 125.15 | 750.225 |
| 100 | 12 500.016 | 6 250.033 | 4 166.716 | 3 125.066 | 2 500.083 | 2 083.433 | 1 785.83 | 1 562.633 | 1 389.038 | 1 250.166 | 833.583 |
| 110 | 13 750.018 | 6 875.036 | 4 583.388 | 3 437.573 | 2 750 091 | 2 291.776 | 1 964.414 | 1 718.896 | 1 527.942 | 1 375.183 | 916.941 |
| 120 | 15 000.02 | 7 500.04 | 5 000.06 | 3 750.08 | 3 000.1 | 2 500.12 | 2 142 997 | 1 875.16 | 1 666.846 | 1 500 2 | 1 000.3 |
| 130 | 16 250.021 | 8 125.043 | 5 416.731 | 4 062.586 | 3 250.108 | 2 708.463 | 2 321.58 | 2 031.423 | 1 805.75 | 1 625.216 | 1 083.658 |
| 140 | 17 500.023 | 8 750.046 | 5 833.408 | 4 375.093 | 3 500.116 | 2 916.806 | 2 500.163 | 2 187.686 | 1 944.654 | 1 750.233 | 1 167.016 |
| 150 | 18 750.025 | 9 375.05 | 6 250.075 | 4 687.6 | 3 750.125 | 3 125.15 | 2 678.746 | 2 343.95 | 2 083.558 | 1 875.25 | 1 250.375 |
| 160 | 20 000.026 | 10 000.053 | 6 666.746 | 5 000.106 | 4 000.133 | 3 333.493 | 2 857.329 | 2 500.213 | 2 222.462 | 2 000.266 | 1 133.733 |
| 170 | 21 250.028 | 10 625.056 | 7 083.418 | 5 312.613 | 4 250.141 | 3 541.836 | 3 035.912 | 2 656.476 | 2 361.366 | 2 125.283 | 1 417.091 |
| 180 | 22 500.03 | 11 250.06 | 7 500.09 | 5 625.12 | 4 500.15 | 3 750.18 | 3 214.495 | 2 812.74 | 2 500.269 | 2 250.3 | 1 509.45 |
| 190 | 23 750.031 | 11 875.063 | 7 916.761 | 5 937.626 | 4 750.158 | 3 958.523 | 3 393.078 | 2 969.008 | 2 639.178 | 2 375.316 | 1 583.808 |
| 200 | 25 000.033 | 12 500.066 | 8 333.433 | 6 250.133 | 5 000.166 | 4 166.866 | 3 571.661 | 3 125.266 | 2 778.077 | 2 500.333 | 1 667.166 |

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## STRAINS AT CENTERS OF SPANS RESULTING FROM A GIVEN DEFLECTION.—(*Cont.*)

| Spans in feet. | Deflections in decimal parts of spans. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .020 | .025 | 030 | .035 | .040 | .045 | .050 | .055 | .060 | .065 | .070 | .075 |
| | Multipliers. | | | | | | | | | | | |
| 10 | 62.533 | 50.041 | 41.716 | 35.772 | 31.316 | 27.852 | 25.083 | 22.818 | 20.933 | 19.339 | 17.973 | 16.791 |
| 20 | 125.066 | 100.083 | 83.433 | 71.545 | 62.633 | 55.705 | 50.166 | 45.637 | 41.866 | 38.678 | 35.947 | 33.583 |
| 30 | 187.6 | 150.125 | 125.15 | 107.317 | 93.950 | 83.558 | 75.25 | 68.456 | 62.8 | 58 017 | 53.921 | 50.375 |
| 40 | 250.133 | 200.166 | 166.866 | 143.09 | 125.266 | 111.411 | 100.333 | 91.275 | 83.733 | 77.356 | 71.895 | 67.166 |
| 50 | 312.666 | 250.208 | 208.583 | 178.863 | 156.583 | 139.263 | 125.416 | 114.094 | 104.666 | 96.695 | 89.869 | 83.958 |
| 60 | 375.2 | 300.25 | 250.3 | 214.635 | 187.900 | 167.116 | 150.5 | 136.913 | 125.6 | 116.034 | 107.042 | 100.75 |
| 70 | 437.733 | 350.291 | 292.016 | 250.408 | 219.216 | 194.969 | 175.583 | 159.732 | 146.533 | 135.373 | 125.816 | 117.541 |
| 80 | 500.266 | 400.333 | 333.733 | 286.18 | 250.533 | 222.822 | 200.666 | 182.551 | 167.466 | 154.712 | 143.79 | 134.333 |
| 90 | 562.8 | 450.375 | 375.45 | 321.958 | 281.850 | 250.674 | 225.75 | 205.37 | 188.4 | 174.051 | 161.764 | 151.125 |
| 100 | 625 333 | 500.416 | 417.166 | 357.726 | 313.166 | 278.527 | 250.833 | 228.189 | 209.333 | 193.391 | 179.738 | 167.916 |
| 110 | 687.866 | 550.458 | 458.883 | 393.498 | 344.483 | 306.38 | 275.916 | 251.008 | 230.266 | 212.73 | 197.711 | 184.708 |
| 120 | 750.4 | 600.5 | 500.6 | 429.271 | 375.800 | 334.233 | 301. | 273.827 | 251.2 | 232.069 | 215.685 | 201.5 |
| 130 | 812.933 | 650.541 | 542.316 | 465.044 | 407.116 | 362.086 | 326.083 | 296.646 | 272.133 | 251.408 | 233.659 | 218.291 |
| 140 | 875.466 | 700.583 | 584.033 | 500.816 | 438.433 | 389.938 | 351.166 | 319.465 | 293.066 | 270.747 | 251.633 | 235.083 |
| 150 | 938. | 750.625 | 625.75 | 536.589 | 469.750 | 417.791 | 376.25 | 342.284 | 314. | 290.086 | 269.607 | 251.875 |
| 160 | 1 000.533 | 800.666 | 667.466 | 572.361 | 501.066 | 445.644 | 401.333 | 365.103 | 334.933 | 309.425 | 287.58 | 268.666 |
| 170 | 1 063.066 | 850.708 | 709.183 | 608.134 | 532.383 | 473.497 | 426.416 | 387.921 | 355.866 | 328.764 | 305.554 | 285.458 |
| 180 | 1 125.6 | 900.75 | 750.9 | 643.907 | 563.7 | 501.349 | 451.5 | 410.74 | 376.8 | 348.103 | 323.528 | 302.25 |
| 190 | 1 188.133 | 950.791 | 792.616 | 679.679 | 595.016 | 529.202 | 476.583 | 433.559 | 397.733 | 367.442 | 341.502 | 319.041 |
| 200 | 1 250.666 | 1 000.833 | 834.333 | 715.452 | 626.333 | 557.055 | 501.666 | 456.378 | 418.666 | 386.782 | 359.476 | 335.833 |

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## STRAINS AT CENTERS OF SPANS RESULTING FROM A GIVEN DEFLECTION.—(*Cont.*)

| Spans in feet. | Deflections in decimal parts of spans. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .080 | .085 | .090 | .095 | .100 | .110 | .120 | .130 | .140 | .150 | .160 | .170 | .180 | .190 | .200 |
| | Multipliers. | | | | | | | | | | | | | | |
| 10 | 15.758 | 14.847 | 14.038 | 13.316 | 12.666 | 11.546 | 10.616 | 9.832 | 9.161 | 8.583 | 8.079 | 7.636 | 7.244 | 6.895 | 6.583 |
| 20 | 31.516 | 29.695 | 28.077 | 26.632 | 25.333 | 23.093 | 21.233 | 19.664 | 18.323 | 17.166 | 16.158 | 15.272 | 14.488 | 13.791 | 13.166 |
| 30 | 47.275 | 44.542 | 42.116 | 39.948 | 38. | 34.64 | 31 85 | 29.496 | 27.485 | 25.75 | 24.237 | 22.908 | 21.733 | 20.686 | 19.75 |
| 40 | 63.033 | 59.39 | 56.155 | 53.264 | 50.666 | 46.187 | 42.466 | 39.328 | 36.647 | 34.333 | 32.316 | 30.545 | 28.977 | 27.582 | 26.333 |
| 50 | 78.791 | 74.237 | 70.194 | 66.581 | 63.333 | 57.734 | 53.083 | 49.16 | 45.809 | 42.916 | 40.395 | 38.181 | 36.222 | 34.478 | 32.916 |
| 60 | 94.55 | 89.085 | 84.233 | 79.897 | 76. | 69.281 | 63.7 | 58.992 | 54.971 | 51.5 | 48.475 | 45.817 | 43.466 | 41.373 | 39.5 |
| 70 | 110.308 | 103.932 | 98.272 | 93.213 | 88.666 | 80.828 | 74.316 | 68.824 | 64.133 | 60.083 | 56.554 | 53.453 | 50.711 | 48.269 | 46.083 |
| 80 | 126.066 | 118.78 | 112.311 | 106.529 | 101.333 | 92.375 | 84.933 | 78.656 | 73.295 | 68.666 | 64.633 | 61.09 | 57.955 | 55.164 | 52.666 |
| 90 | 141.825 | 133.627 | 126.35 | 119.846 | 114. | 103.922 | 95.55 | 88.488 | 82.457 | 77.25 | 72.712 | 68.726 | 65.199 | 62.06 | 59.25 |
| 100 | 157.583 | 148.475 | 140.388 | 133.162 | 126.666 | 115.469 | 106.166 | 98.32 | 91.619 | 85.833 | 80.791 | 76.362 | 72.444 | 68.956 | 65.833 |
| 110 | 173.341 | 163.323 | 154.427 | 146.478 | 139.333 | 127.016 | 116.783 | 108.152 | 100.78 | 94.416 | 88.87 | 83.999 | 79.688 | 75.851 | 72.416 |
| 120 | 189.1 | 178.17 | 168.466 | 159.794 | 152. | 138.563 | 127.4 | 117.984 | 109.942 | 103. | 96.95 | 91.635 | 86.933 | 82.747 | 79. |
| 130 | 204.858 | 193.018 | 182.505 | 173.11 | 164.666 | 150.11 | 138.016 | 127.816 | 119.104 | 111.583 | 105.029 | 99.271 | 94.177 | 89.642 | 85.583 |
| 140 | 220.616 | 207.865 | 196.544 | 186.427 | 177.333 | 161.657 | 148.633 | 137.648 | 128.266 | 120.166 | 113.108 | 106.907 | 101.422 | 96.538 | 92.166 |
| 150 | 236.375 | 222.713 | 210.583 | 199.743 | 190. | 173.204 | 159.25 | 147.48 | 137.428 | 128.75 | 121.187 | 114.544 | 108.666 | 103.434 | 98.75 |
| 160 | 252.133 | 237.56 | 224.622 | 213.059 | 202.666 | 184.751 | 169.866 | 157.312 | 146.59 | 137.333 | 129.266 | 122.18 | 115.911 | 110.329 | 105.333 |
| 170 | 267.891 | 252.408 | 238.661 | 226.375 | 215.333 | 196.298 | 180.483 | 167.144 | 155.752 | 145.916 | 137.345 | 129.816 | 123.155 | 117.225 | 111.916 |
| 180 | 283.65 | 267.255 | 252.7 | 239.692 | 228. | 207.845 | 191.1 | 176.976 | 164.914 | 154.5 | 145.425 | 137.452 | 130.399 | 124.121 | 118.5 |
| 190 | 299.408 | 282.103 | 266.738 | 253.008 | 240.666 | 219.392 | 201.716 | 186.808 | 174.076 | 163.083 | 153.504 | 145.089 | 137.644 | 131.016 | 125.083 |
| 200 | 315.166 | 296.95 | 280.777 | 266.324 | 253.333 | 230.939 | 212.333 | 196.641 | 183.238 | 171.666 | 161.583 | 152.725 | 144.888 | 137.912 | 131.666 |

RULE.—To find strain in pounds on wire of given span and deflection, multiply numbers in column answering to span and deflection by the weight per foot of wire.

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## TEMPERATURE EFFECTS IN SPANS.

| Spans in feet. | Temperature in degrees Fahrenheit. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | —10° | 30° | 40° | 50° | 60° | 70° | 80° | 90° | 100° |
| | Deflections in inches. | | | | | | | | |
| 50 | .5 | 6 | 8 | 9 | 9 | 10 | 11 | 11 | 12 |
| 60 | .7 | 8 | 10 | 11 | 11 | 12 | 13 | 13 | 14 |
| 70 | 1. | 10 | 11 | 12 | 13 | 14 | 15 | 15 | 17 |
| 80 | 1.2 | 11 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 90 | 1.6 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 21 |
| 100 | 1.9 | 14 | 16 | 17 | 19 | 20 | 21 | 23 | 24 |
| 110 | 2.3 | 16 | 18 | 19 | 21 | 22 | 24 | 25 | 26 |
| 120 | 2.8 | 17 | 19 | 21 | 22 | 24 | 26 | 27 | 28 |
| 130 | 3.2 | 19 | 21 | 23 | 25 | 26 | 28 | 29 | 31 |
| 140 | 3.7 | 20 | 23 | 25 | 27 | 28 | 30 | 32 | 33 |
| 150 | 4.3 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
| 160 | 4.9 | 23 | 26 | 28 | 30 | 32 | 34 | 36 | 38 |
| 170 | 5.5 | 25 | 28 | 30 | 32 | 35 | 37 | 38 | 40 |
| 180 | 6.2 | 26 | 29 | 32 | 34 | 37 | 39 | 41 | 43 |
| 190 | 7. | 28 | 31 | 34 | 36 | 39 | 41 | 43 | 45 |
| 200 | 7.7 | 31 | 33 | 36 | 38 | 41 | 43 | 45 | 48 |

Hard-drawn copper wire, 60 000 pounds strength per square inch.

Strain at —10° F., 30 000 pounds per square inch.

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# TOTAL LENGTHS OF WIRES IN SPANS.

| Spans in feet. | Deflections in decimal parts of spans. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .010 | .015 | .020 | .025 | .030 | .035 | .040 | .045 | .050 | .055 | .060 | .070 | .080 |
| | Lengths of wires. | | | | | | | | | | | | |
| 10 | 10.002 | 10.006 | 10.01 | 10.016 | 10.024 | 10.032 | 10.042 | 10.054 | 10.066 | 10.08 | 10.096 | 10.13 | 10.17 |
| 20 | 20.005 | 20.012 | 20.021 | 20.033 | 20.048 | 20.065 | 20.085 | 20.108 | 20.133 | 20.161 | 20.192 | 20.261 | 20.341 |
| 30 | 30.008 | 30.018 | 30.032 | 30.05 | 30.072 | 30.098 | 30.128 | 30.162 | 30.2 | 30.242 | 30.288 | 30.392 | 30.512 |
| 40 | 40.01 | 40.024 | 40.042 | 40.066 | 40.096 | 40.13 | 40.17 | 40.216 | 40.266 | 40.322 | 40.384 | 40.522 | 40.682 |
| 50 | 50.013 | 50.03 | 50.053 | 50.083 | 50.12 | 50.163 | 50.213 | 50.27 | 50.333 | 50.403 | 50.48 | 50.653 | 50.853 |
| 60 | 60.016 | 60.036 | 60.064 | 60.1 | 60.144 | 60.196 | 60.256 | 60.324 | 60.4 | 60.484 | 60.576 | 60.784 | 61.024 |
| 70 | 70.018 | 70.042 | 70.074 | 70.116 | 70.168 | 70.228 | 70.298 | 70.378 | 70.466 | 70.564 | 70.672 | 70.914 | 71.194 |
| 80 | 80.021 | 80.048 | 80.085 | 80.133 | 80.192 | 80.261 | 80.341 | 80.432 | 80.533 | 80.645 | 80.768 | 81.045 | 81.365 |
| 90 | 90.024 | 90.054 | 90.096 | 90.15 | 90.216 | 90.294 | 90.384 | 90.486 | 90.6 | 90.726 | 90.864 | 91.176 | 91.536 |
| 100 | 100.026 | 100.06 | 100.106 | 100.166 | 100.24 | 100.326 | 100.426 | 100.54 | 100.666 | 100.806 | 100.96 | 101.306 | 101.706 |
| 110 | 110.029 | 110.066 | 110.117 | 110.183 | 110.264 | 110.359 | 110.469 | 110.594 | 110.733 | 110.887 | 111.056 | 111.437 | 111.877 |
| 120 | 120.032 | 120.072 | 120.128 | 120.2 | 120.288 | 120.392 | 120.512 | 120.648 | 120.8 | 120.968 | 121.152 | 121.568 | 122.048 |
| 130 | 130.034 | 130.078 | 130.138 | 130.216 | 130.312 | 130.424 | 130.554 | 130.702 | 130.866 | 131.048 | 131.248 | 131.698 | 132.218 |
| 140 | 140.037 | 140.084 | 140.149 | 140.233 | 140.336 | 140.457 | 140.597 | 140.756 | 140.933 | 141.129 | 141.344 | 141.829 | 142.389 |
| 150 | 150.04 | 150.09 | 150.16 | 150.25 | 150.36 | 150.49 | 150.64 | 150.81 | 151. | 151.21 | 151.44 | 151.96 | 152.56 |
| 160 | 160.04 | 160.096 | 160.17 | 160.266 | 160.384 | 160.522 | 160.682 | 160.864 | 161.066 | 161.29 | 161.536 | 162.09 | 162.73 |
| 170 | 170.045 | 170.102 | 170.181 | 170.283 | 170.408 | 170.555 | 170.725 | 170.918 | 171.133 | 171.371 | 171.632 | 172.221 | 172.901 |
| 180 | 180.048 | 180.108 | 180.192 | 180.3 | 180.432 | 180.588 | 180.768 | 180.972 | 181.2 | 181.452 | 181.728 | 182.352 | 183.072 |
| 190 | 190.05 | 190.114 | 190.202 | 190.316 | 190.456 | 190.62 | 190 81 | 191.026 | 191.266 | 191.532 | 191.824 | 192.482 | 193.242 |
| 200 | 200.053 | 200.12 | 200.213 | 200.333 | 200.48 | 200.653 | 200.853 | 201.08 | 201.333 | 201.613 | 201.92 | 202.613 | 203.413 |

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## TOTAL LENGTHS OF WIRES IN SPANS.—(*Continued.*)

| Spans in feet. | Deflections in decimal parts of spans. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .090 | .100 | .110 | .120 | .130 | .140 | .150 | .160 | .170 | .180 | .190 | .200 |
| | Lengths of wires. | | | | | | | | | | | |
| 10 | 10.216 | 10.266 | 10.322 | 10.384 | 10.45 | 10.522 | 10.6 | 10.682 | 10.77 | 10.864 | 10.962 | 11.066 |
| 20 | 20.432 | 20.533 | 20.645 | 20.768 | 20.901 | 21.045 | 21.2 | 21.365 | 21.541 | 21.728 | 21.925 | 22.133 |
| 30 | 30.648 | 30.8 | 30.968 | 31.152 | 31.352 | 31.568 | 31.8 | 32.048 | 32.312 | 32.592 | 32.888 | 33.2 |
| 40 | 40.864 | 41.066 | 41.29 | 41.536 | 41.802 | 42.09 | 42.4 | 42.73 | 43.082 | 43.456 | 43.85 | 44.266 |
| 50 | 51.08 | 51.333 | 51.613 | 51.92 | 52.253 | 52.613 | 53. | 53.413 | 53.853 | 54.32 | 54.813 | 55.333 |
| 60 | 61.296 | 61.6 | 61.936 | 62.304 | 62.704 | 63.136 | 63.6 | 64.096 | 64 624 | 65.184 | 65.776 | 66.4 |
| 70 | 71.512 | 71.866 | 72.258 | 72.688 | 73.154 | 73.658 | 74.2 | 74.778 | 75.394 | 76.048 | 76.738 | 77.466 |
| 80 | 81.728 | 82.133 | 82.581 | 83.072 | 83.605 | 84.181 | 84.8 | 85.461 | 86.165 | 86.912 | 87.701 | 88.533 |
| 90 | 91.944 | 92.4 | 92.904 | 93.456 | 94.056 | 94.704 | 95.4 | 96.144 | 96.936 | 97.776 | 98.664 | 99.6 |
| 100 | 102.16 | 102.666 | 103.226 | 103.84 | 104.506 | 105.226 | 106. | 106.826 | 107.706 | 108.64 | 109.626 | 110.666 |
| 110 | 112.376 | 112.933 | 113.549 | 114.224 | 114.957 | 115.749 | 116.6 | 117.509 | 118.477 | 119.504 | 120.589 | 121.733 |
| 120 | 122.592 | 123.2 | 123 872 | 124.608 | 125.408 | 126.272 | 127.2 | 128.192 | 129.248 | 130.368 | 131.552 | 132.8 |
| 130 | 132.808 | 133.466 | 134.194 | 134.992 | 135.858 | 136.794 | 137.8 | 138.874 | 140.018 | 141.232 | 142.514 | 143.866 |
| 140 | 143.024 | 143.733 | 144.517 | 145.376 | 146.309 | 147.317 | 148.4 | 149.557 | 150.789 | 152.096 | 153.477 | 154.933 |
| 150 | 153.24 | 154. | 154.84 | 155.76 | 156.76 | 157.84 | 159. | 160.24 | 161.56 | 162.96 | 164.44 | 166. |
| 160 | 163.456 | 164.266 | 165.162 | 166.144 | 167.21 | 168.362 | 169.6 | 170.922 | 172.33 | 173.824 | 175.402 | 177.066 |
| 170 | 173.672 | 174.533 | 175.485 | 176.528 | 177.661 | 178.885 | 180.2 | 181.605 | 183.101 | 184.688 | 186.365 | 188.133 |
| 180 | 183.888 | 184.8 | 185.808 | 186.912 | 188.112 | 189.408 | 190.8 | 192.288 | 193.872 | 195.552 | 197.328 | 199.2 |
| 190 | 194.104 | 195.066 | 196.18 | 197.296 | 198.562 | 199.93 | 201.4 | 202.97 | 204.642 | 206.416 | 208.29 | 210.166 |
| 200 | 204.32 | 205.333 | 206.453 | 207.68 | 209.013 | 210.458 | 212. | 213.653 | 215.413 | 217.28 | 219.253 | 221.333 |

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## WEATHERPROOF WIRE.

Our Weatherproof wire is put on reels in long lengths, and has a hard, smooth finish, presenting the least possible chance for adherence of ice and snow. We keep in stock all sizes given in the accompanying table, to 0 000 B. & S., in both double and triple braid.

In the Stranded wires, we keep only the most commonly used sizes. We make this Feed Wire Strand either concentric or cable-laid, as desired.

## FIRE AND WEATHERPROOF WIRE.

For interior work, we manufacture a Fire and Weatherproof insulation. Full information concerning weights, diameters and prices furnished on application.

## UNDERWRITERS' WIRE.

Underwriters' wire seems to be used chiefly for inside work. Its weight is about the same as double-braid Weatherproof.

## WEATHERPROOF IRON WIRE.

We keep in stock 10, 12 and 14 B. W. G., both double and triple braid.

| Numbers, B. W. G. | Weights per mile. Pounds. | | Lengths in coils. Miles. |
|---|---|---|---|
| | Double braid. | Triple braid. | |
| 4 | 997 | 1 102 | 1/8 |
| 6 | 713 | 773 | 1/8 |
| 8 | 483 | 548 | 1/4 |
| 9 | 403 | 464 | 1/8 |
| 10 | 350 | 410 | 1/8 |
| 12 | 240 | 265 | 1/8 |
| 14 | 150 | 176 | 1/8 |

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## WEATHERPROOF WIRE.

| Numbers, B. & S. G. | Double braid. Outside diameters in 32ds inch. | Double braid. Weights. Pounds. 1 000 feet. | Double braid. Weights. Pounds. Mile. | Triple braid. Outside diameters in 32ds inch. | Triple braid. Weights. Pounds. 1 000 feet. | Triple braid. Weights. Pounds. Mile. | Approximate weights. Pounds. Reel. | Approximate weights. Pounds. Coil. |
|---|---|---|---|---|---|---|---|---|
| 0 000 | 20 | 716 | 3 781 | 24 | 775 | 4 092 | 2 000 | 250 |
| 000 | 18 | 575 | 3 036 | 22 | 630 | 3 326 | 2 000 | 250 |
| 00 | 17 | 465 | 2 455 | 18 | 490 | 2 587 | 500 | 250 |
| 0 | 16 | 375 | 1 980 | 17 | 400 | 2 112 | 500 | 250 |
| 1 | 15 | 285 | 1 505 | 16 | 306 | 1 616 | 500 | 250 |
| 2 | 14 | 245 | 1 294 | 15 | 268 | 1 415 | 500 | 250 |
| 3 | 13 | 190 | 1 003 | 14 | 210 | 1 109 | 500 | 250 |
| 4 | 11 | 152 | 803 | 12 | 164 | 866 | 250 | 125 |
| 5 | 10 | 120 | 634 | 11 | 145 | 766 | 260 | 130 |
| 6 | 9 | 98 | 518 | 10 | 112 | 591 | 275 | 140 |
| 8 | 8 | 66 | 349 | 9 | 78 | 412 | 200 | 100 |
| 10 | 7 | 45 | 238 | 8 | 55 | 290 | 200 | 100 |
| 12 | 6 | 30 | 158 | 7 | 35 | 185 | ..... | 25 |
| 14 | 5 | 20 | 106 | 6 | 26 | 137 | ..... | 25 |
| 16 | 4 | 14 | 74 | 5 | 20 | 106 | ..... | 25 |
| 18 | 3 | 10 | 53 | 4 | 16 | 85 | ..... | 25 |

## STRANDED WEATHERPROOF FEED WIRE.

| Circular mils. | Outside diameters. Inches. | Weights. Pounds. 1 000 feet. | Weights. Pounds. Mile. | Approximate length on reels. Feet. |
|---|---|---|---|---|
| 1 000 000 | 1 1/32 | 3 550 | 18 744 | 800 |
| 900 000 | 1 1/32 | 3 215 | 16 975 | 800 |
| 800 000 | 1 1/32 | 2 880 | 15 206 | 850 |
| 750 000 | 1 1/32 | 2 713 | 14 325 | 850 |
| 700 000 | 1 1/32 | 2 545 | 13 438 | 900 |
| 650 000 | 1 1/4 | 2 378 | 12 556 | 900 |
| 600 000 | 1 3/32 | 2 210 | 11 668 | 1 000 |
| 550 000 | 1 1/16 | 2 043 | 10 787 | 1 200 |
| 500 000 | 1 1/8 | 1 875 | 9 900 | 1 320 |
| 450 000 | 1 3/32 | 1 703 | 8 992 | 1 400 |
| 400 000 | 1 1/16 | 1 530 | 8 078 | 1 450 |
| 350 000 | 1 | 1 358 | 7 170 | 1 500 |
| 300 000 | 31/32 | 1 185 | 6 257 | 1 600 |
| 250 000 | 29/32 | 1 012 | 5 343 | 1 600 |

The table is calculated for concentric strands. Rope-laid strands are larger.

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## RUBBER WIRE.

WE MANUFACTURE rubber insulated wires for all purposes, including wires and cables for aerial, underground, and submarine use. The copper conductor is tinned, and then covered with a cement of pure rubber, which causes the succeeding coat of rubber to adhere firmly to the wire. This layer consists of white rubber without sulphur. Over this is a layer of vulcanized rubber, and the whole is covered with a finishing braid of cotton saturated with a Weatherproof compound, which protects the rubber from mechanical injury, and from the action of the air. A poor quality of rubber insulation is inferior to Weatherproof, and we would recommend our Fire and Weatherproof insulation for inside work, rather than an inferior rubber wire.

A good rubber wire should have its conductor central, the insulation should adhere firmly to the wire, it should not crack or become brittle after use, and it should show, after immersion in water for twenty-four hours, the same insulation resistance per mile as when tested after being first put in water. The absolute number of megohms per mile depends on the age of the rubber used, together with other details of manufacture, and is not always a sure guide to the quality of the insulation. Uniformity of insulation among several coils of wire made at the same time, or among the various conductors of a cable, is a much more valuable aid in detecting a poor piece of wire, as in this case an insulation lower than the average shows a local defect, which, in time, will be likely to cause trouble.

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# CRESCENT RUBBER WIRE

## Stranded conductors.

| Numbers, B. & S. G. | Circular mils. | Outside diameters. Inches. | Weights per 1 000 feet. Pounds. | Sizes of wires in strands. B. & S. G. | |
|---|---|---|---|---|---|
| | | | | Regular. | Flexible. |
| ..... | 1 000 000 | $1\frac{7}{16}$ | 3 690 | 8 | 12 |
| ..... | 900 000 | $1\frac{11}{32}$ | 3 370 | 8 | 12 |
| ..... | 800 000 | $1\frac{9}{32}$ | 3 020 | 8 | 12 |
| ..... | 700 000 | $1\frac{7}{32}$ | 2 685 | 10 | 12 |
| ..... | 600 000 | $1\frac{5}{32}$ | 2 345 | 10 | 12 |
| ..... | 500 000 | $1\frac{1}{16}$ | 1 885 | 10 | 14 |
| ..... | 450 000 | $1\frac{1}{32}$ | 1 723 | 10 | 14 |
| ..... | 400 000 | 1 | 1 560 | 10 | 14 |
| ..... | 350 000 | $\frac{15}{16}$ | 1 378 | 10 | 14 |
| ..... | 300 000 | $\frac{7}{8}$ | 1 155 | 10 | 14 |
| | 250 000 | $\frac{27}{32}$ | 995 | 10 | 14 |
| 0 000 | ..... | $\frac{25}{32}$ | 866 | 10 | 15 |
| 000 | ..... | $\frac{23}{32}$ | 725 | 10 | 15 |
| 00 | ..... | $\frac{11}{16}$ | 613 | 11 | 15 |

| Numbers, B. & S. G. | Outside diameters in 32ds of an inch. | | Weights per 1 000 feet. Pounds. | Sizes of wires in strand. B. & S. G. | |
|---|---|---|---|---|---|
| | Solid. | Stranded. | | Regular. | Flexible. |
| 0 | 18 | 20 | 489 | 12 | 16 |
| 1 | 16 | 18 | 393 | 12 | 16 |
| 2 | 14 | 15 | 309 | 12 | 18 |
| 3 | 13 | 14 | 244 | 13 | 18 |
| 4 | 12 | 13 | 198 | 14 | 20 |
| 5 | 11 | 12 | 168 | 15 | 20 |
| 6 | 10 | 11 | 146 | 16 | 20 |
| 8 | 9 | 10 | 106 | 18 | 22 |
| 10 | 8 | 8 | 77 | 20 | 25 |
| 12 | 7 | 7 | 55 | 20 | 25 |
| 14 | 6 | 6 | 35 | 21 | 25 |
| 16 | 5 | 5 | 25 | 23 | 25 |
| 18 | 4 | 4 | 20 | 25 | 25 |

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## MAGNET WIRE.

THE BARE COPPER intended for Magnet wire is specially drawn and annealed, great care being taken to have it true to gauge, and soft.

A difference from the standard, of one mil, is allowed on sizes larger than No. 10 B. & S. G.; from No. 10 to No. 14, three-fourths of a mil variation is allowed, and any wire smaller than No. 14, one-half a mil variation is allowed.

The insulation is smooth and uniform, and is kept true to gauge to within one mil of the required diameter.

We manufacture any special kind of Magnet wire required, flats, squares and strands.

We understand that a No. 6 B. & S. square Magnet wire measures 162 x 162 mils.

Flats are designated by their width and thickness. Thus a flat Magnet wire 340 mils wide and 40 mils thick would be designated as a 340 x 40 flat Magnet wire.

Strands can be furnished of any size, insulated with double or triple windings of cotton, or any combination of braids and windings that may be desired.

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## MAGNET WIRE.

| Numbers, B. & S. G. | Diameter drawn. Mils. | Outside diameters. Mils. | | Approximate weights on reels. Pounds. |
|---|---|---|---|---|
| | | Double. | Single. | |
| 0 | 325 | 343 | 337 | 200 |
| 1 | 289 | 307 | 301 | 200 |
| 2 | 258 | 276 | 270 | 200 |
| 3 | 229 | 247 | 241 | 200 |
| 4 | 204 | 222 | 216 | 200 |
| 5 | 182 | 200 | 194 | 200 |
| 6 | 162 | 178 | 172 | 200 |
| 7 | 144 | 160 | 154 | 200 |
| 8 | 128 | 142 | 137 | 200 |
| 9 | 114 | 126 | 122 | 200 |
| 10 | 102 | 112 | 108 | 200 |
| 11 | 91 | 101 | 97 | 200 |
| 12 | 81 | 91 | 87 | 200 |
| 13 | 72 | 81 | 78 | 160 |
| 14 | 64 | 73 | 70 | 160 |
| 15 | 57 | 66 | 63 | 50 |
| 16 | 51 | 60 | 57 | 50 |
| 17 | 45 | 54 | 51 | 50 |
| 18 | 40 | 49 | 46 | 50 |
| 19 | 36 | 45 | 42 | 50 |

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## GERMAN SILVER WIRE.

| Numbers, B. & S. G. | Resistance per 1 000 feet. | | Numbers, B. & S. G. | Resistance per 1 000 feet. | |
|---|---|---|---|---|---|
| | 18 per centum. | 30 per centum. | | 18 per centum. | 30 per centum. |
| 6 | 7.20 | 11.21 | 22 | 295.38 | 459.48 |
| 7 | 9.12 | 14.18 | 23 | 370.26 | 575.96 |
| 8 | 11.54 | 17.95 | 24 | 468.18 | 728.28 |
| 9 | 14.55 | 22.63 | 25 | 590.22 | 918.12 |
| 10 | 18.18 | 28.28 | 26 | 748.08 | 1 163.68 |
| 11 | 22.84 | 35.53 | 27 | 937.98 | 1 459.08 |
| 12 | 28.81 | 44.82 | 28 | 1 191.24 | 1 853.04 |
| 13 | 36.48 | 56.75 | 29 | 1 481.22 | 2 304.12 |
| 14 | 46.17 | 71.82 | 30 | 1 891.8 | 2 942.8 |
| 15 | 58.21 | 90.55 | 31 | 2 388.6 | 8 715.6 |
| 16 | 72.72 | 113.12 | 32 | 2 955.6 | 4 597.6 |
| 17 | 93.40 | 145.29 | 33 | 3 751.2 | 5 835.2 |
| 18 | 118.20 | 183.87 | 34 | 4 764.6 | 7 411.6 |
| 19 | 145.94 | 227.02 | 35 | 6 031.8 | 9 382.8 |
| 20 | 184.68 | 287.28 | 36 | 7 565.4 | 11 768.4 |
| 21 | 232.92 | 362.32 | ... | ..... | ..... |

The resistance of German silver wire varies according to the method of manufacture and the materials used.

From actual tests on wire with eighteen per centum of nickel, extending over ten years, it seems that eighteen times the resistance of copper, at 75° F., represents very closely the resistance of this alloy. This value is rather under than over the average results of the tests.

For the thirty per centum alloy, we have to depend on the results of a single series of tests, and while the results are believed to be correct, they are not as reliable as those given for the eighteen per centum German silver wire. We take the resistance of the thirty per centum alloy at twenty-eight times the resistance of copper, at 75°.

The International ohm is taken as the unit of resistance.

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## OFFICE WIRES.

Office wire is usually made with a wind and a braid of cotton saturated with paraffine. It is sometimes required with a double braid or triple braid of cotton. The most common colors are red and white. Any combination of colors can be furnished.

Damp-proof Office wire has the inside wind saturated with black Weatherproof compound, while the outside finish is the same as ordinary Office wire.

Annunciator wire has a covering consisting of two wraps of cotton saturated with paraffine. The outer covering is made in solid colors or combination of two colors.

Double conductors for house wiring are of various kinds. Two conductors twisted together, without any outside cover, form a convenient method of wiring for bells, telephones, etc. These conductors may be 18 B. & S., with double braid Weatherproof or with Annunciator insulation.

Two-conductor Office wire may be two Office wires laid side by side and covered with a two-colored Office braid, or it may consist of two Annunciator wires so insulated.

Weatherproof cables consist of 18 B. & S. G. Annunciator wires, twisted into a cable and covered with rubber tape and a braid of cotton saturated with Weatherproof insulation. They weigh about ten pounds per 1 000 feet per conductor. For work inside building, in dry places, the rubber tape may be omitted, and the finishing braid made any color to correspond with the woodwork.

Lamp cord is furnished in silk or cotton insulation. Green and yellow is the standard color combination.

| Numbers, B. & S. G. | Weights per 1 000 feet. | | Sizes of Lamp cord. | |
|---|---|---|---|---|
| | Office wire. | Annunciator wire. | Silk. | Cotton. |
| 14 | 17 | 15 | 1/4 | 1/16 |
| 16 | 12 | 10 | 1/8 | 1/4 |
| 18 | 9 | 7 | 1/16 | 1/16 |
| 20 | 7 | 4½ | 1/8 | 1/16 |

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## POWER CABLES.

WE MANUFACTURE power and electric-light cables, with jute, paper or rubber insulation. The thickness and kind of insulation depend on the use for which the cable is intended. The table of diameters and weights is based on $\frac{3}{16}$ insulation on a side, and is approximately correct for any kind of insulation.

### Specifications for Underground Cable of 500 000 C. M.

1. COPPER CONDUCTOR.

The conductor shall consist of 47 wires, each 104 mils in diameter, and shall weigh not less than 1.525 pounds per foot. The copper used shall have a conductivity of not less than 98 per cent.

2. INSULATION.

The insulation shall consist of paper not less than $\frac{3}{16}$ thick, and shall form a wall of uniform thickness around the conductor.

3. SHEATH.

The insulated conductor shall be enclosed in a pipe composed of lead and tin. The amount of tin shall not be less than 2.9 per cent. The pipe shall be formed around the core, and shall be free from holes or other defects, and of uniform thickness and composition.

4. INSULATION RESISTANCE.

The insulation resistance shall be not less than 300 megohms per mile, at 60° F.

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## POWER CABLES.

| Numbers, B. & S. G. | Circular mils. | Outside diameters. Inches. | Weights, 1 000 feet. Pounds. |
|---|---|---|---|
| ..... | 1 000 000 | $1\frac{13}{16}$ | 6 685 |
| ..... | 900 000 | $1\frac{23}{32}$ | 6 228 |
| ..... | 800 000 | $1\frac{11}{16}$ | 5 773 |
| ..... | 750 000 | $1\frac{5}{8}$ | 5 543 |
| ..... | 700 000 | $1\frac{19}{32}$ | 5 315 |
| ..... | 650 000 | $1\frac{9}{16}$ | 5 088 |
| ..... | 600 000 | $1\frac{17}{32}$ | 4 857 |
| ..... | 550 000 | $1\frac{1}{2}$ | 4 630 |
| ..... | 500 000 | $1\frac{7}{16}$ | 4 278 |
| ..... | 450 000 | $1\frac{3}{8}$ | 3 923 |
| ..... | 400 000 | $1\frac{11}{32}$ | 3 619 |
| ..... | 350 000 | $1\frac{5}{16}$ | 3 416 |
| ..... | 300 000 | $1\frac{1}{4}$ | 3 060 |
| ..... | 250 000 | $1\frac{3}{16}$ | 2 732 |
| 0 000 | 211 600 | $1\frac{3}{32}$ | 2 533 |
| 000 | 168 100 | $1\frac{1}{16}$ | 2 300 |
| 00 | 133 225 | 1 | 2 021 |
| 0 | 105 625 | $\frac{15}{16}$ | 1 772 |
| 1 | 83 521 | $\frac{29}{32}$ | 1 633 |
| 2 | 66 564 | $\frac{7}{8}$ | 1 482 |
| 3 | 52 441 | $\frac{25}{32}$ | 1 360 |
| 4 | 41 616 | $\frac{3}{4}$ | 1 251 |
| 6 | 26 244 | $\frac{11}{16}$ | 1 046 |

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## TELEPHONE CABLES.

**Lead-encased for underground or aerial use.**

THE INSULATION of these cables is dry paper. We manufacture several styles of 19 B. & S. G., 20 B. & S. G., and 22 B. & S. G., according to the use for which they are intended. The most common size is 19 B. & S. G. We also supply terminals and hangers. To determine the size supporting strand to use with these cables, consult tables page 39.

### Specifications for Telephone Cables.

1. CONDUCTORS.

Each conductor shall be .035 89 inches in diameter, (19 B. & S. G.,) and have a conductivity of 98 per cent. of that of pure soft copper.

2. CORE.

The conductor shall be insulated, twisted in pairs, the length of the twist not to exceed three inches, and formed into a core arranged in reverse layers.

3. SHEATH.

The core shall be enclosed in a pipe composed of lead and tin, the amount of the tin shall be not less than 2½ per cent. The pipe shall be formed around the core, and shall be free from holes or other defects, and of uniform thickness and composition.

4. ELECTROSTATIC CAPACITY.

The average electrostatic capacity shall not exceed .080 of a microfarad per mile, each wire being measured against all the rest and a sheath grounded; the electrostatic capacity of any wires so measured shall not exceed .085 of a microfarad per mile.

5. INSULATION RESISTANCE.

Each wire shall show an insulation of not less than 500 megohms per mile, at 60° F., when laid, spliced and connected to terminal ready for use; each wire being measured against all the rest and sheath grounded.

6. CONDUCTOR RESISTANCE.

Each conductor shall have a resistance of not more than 47 B. A. ohms, at 60° F., for each mile of cable, after the cable is laid and connected to the terminals.

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## TELEPHONE CABLES.

| Number pairs. | Outside diameters. Inches. | Weights, 1 000 feet. Pounds. |
|---|---|---|
| 1 | 5/16 | 214 |
| 2 | 3/8 | 302 |
| 3 | 1/2 | 515 |
| 4 | 9/16 | 629 |
| 5 | 5/8 | 747 |
| 6 | 21/32 | 877 |
| 7 | 11/16 | 912 |
| 10 | 13/16 | 1 214 |
| 12 | 15/16 | 1 375 |
| 15 | 1 | 1 566 |
| 18 | 1 1/16 | 1 758 |
| 20 | 1 1/8 | 1 940 |
| 25 | 1 3/16 | 2 332 |
| 30 | 1 7/16 | 2 748 |
| 35 | 1 1/2 | 2 985 |
| 40 | 1 9/16 | 3 176 |
| 45 | 1 5/8 | 3 365 |
| 50 | 1 3/4 | 3 678 |
| 55 | 1 13/16 | 3 867 |
| 60 | 1 7/8 | 4 055 |
| 65 | 1 15/16 | 4 241 |
| 70 | 2 | 4 430 |
| 80 | 2 1/8 | 4 804 |
| 90 | 2 1/4 | 5 180 |
| 100 | 2 3/8 | 5 505 |

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## TELEGRAPH CABLES.

**Lead-encased for underground use.**

THESE cables are made of either rubber, cotton or paper insulation. The sizes and weights are approximately correct for rubber and cotton insulation. Both sizes and weights are slightly reduced for paper insulation. In all cases the cables are lead-encased.

**Specifications for Telegraph Cables.**

1. CONDUCTORS.

Each conductor shall be .064 inches in diameter, (14 B. & S. G.,) and have a conductivity of 98 per cent. of that of pure copper.

2. CORE.

The conductors shall be insulated to $\frac{1}{32}$ with cotton, and formed into a core arranged in reverse layers. This core shall be dried and saturated with approved insulating compound.

3. SHEATH.

The core shall be enclosed in a pipe composed of lead and tin. The amount of tin shall not be less than 2.9 per cent. The pipe shall be formed around the core, and shall be free from holes or other defects, and of uniform thickness and composition.

4. INSULATION RESISTANCE.

The wire shall show an insulation of not less than 300 megohms per mile, at 60° F., when laid, spliced and connected to terminals ready for use, each wire being measured against all the rest and the sheath grounded.

5. CONDUCTOR RESISTANCE.

Each conductor shall have a resistance of not more than 28 International ohms, at 60° F., for each mile of cable, after the cable is laid and connected up to the terminals.

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## TELEGRAPH CABLES.

| Number conductors. | 14 B. & S. G. Insulated to 4/32. | | 16 B. & S. G. Insulated to 3/32. | | 18 B. & S. G. Insulated to 3/32. | |
|---|---|---|---|---|---|---|
| | Outside diameters. Inches. | Weights, 1 000 feet. | Outside diameters. Inches. | Weights, 1 000 feet. | Outside diameters. Inches. | Weights, 1 000 feet. |
| 1 | 3/8 | 308 | 3/8 | 299 | 3/8 | 291 |
| 2 | 7/16 | 438 | 7/16 | 421 | 11/32 | 356 |
| 3 | 1/2 | 573 | 1/2 | 546 | 7/16 | 421 |
| 4 | 5/8 | 810 | 5/8 | 670 | 11/32 | 486 |
| 5 | 3/4 | 972 | 5/8 | 793 | 1/2 | 551 |
| 6 | 11/16 | 1 132 | 11/16 | 946 | 17/32 | 616 |
| 7 | 7/8 | 1 295 | 3/4 | 965 | 5/8 | 681 |
| 10 | 11/16 | 1 512 | 11/16 | 1 155 | 5/8 | 820 |
| 12 | 1 1/16 | 1 873 | 7/8 | 1 327 | 3/4 | 978 |
| 15 | 1 1/16 | 2 263 | 11/16 | 1 518 | 11/16 | 1 148 |
| 18 | 1 1/4 | 2 523 | 1 1/16 | 1 880 | 7/8 | 1 318 |
| 20 | 1 5/16 | 2 756 | 1 1/8 | 2 076 | 11/16 | 1 477 |
| 25 | 1 7/16 | 3 250 | 1 5/16 | 2 496 | 1 | 1 690 |
| 30 | 1 9/16 | 3 515 | 1 5/8 | 2 768 | 1 1/16 | 1 903 |
| 35 | 1 11/16 | 3 910 | 1 7/16 | 3 040 | 1 5/16 | 2 116 |
| 40 | 1 3/4 | 4 175 | 1 1/2 | 3 312 | 1 1/4 | 2 330 |
| 45 | 1 13/16 | 4 441 | 1 9/16 | 3 533 | 1 9/32 | 2 471 |
| 50 | 1 13/16 | 4 835 | 1 5/8 | 3 755 | 1 5/16 | 2 628 |
| 55 | 2 | 5 100 | 1 11/16 | 3 978 | 1 3/8 | 2 866 |
| 60 | 2 1/16 | 5 365 | 1 3/4 | 4 200 | 1 7/16 | 3 104 |
| 65 | 2 1/8 | 5 631 | 1 13/16 | 4 422 | 1 13/32 | 3 245 |
| 70 | 2 3/16 | 5 897 | 1 7/8 | 4 644 | 1 1/2 | 3 402 |
| 80 | 2 5/16 | 6 408 | 2 | 5 087 | 1 5/8 | 3 798 |
| 90 | 2 7/16 | 6 916 | 2 1/16 | 5 402 | 1 11/16 | 4 027 |
| 100 | 2 9/16 | 7 375 | 2 1/8 | 5 720 | 1 3/4 | 4 275 |

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## AERIAL CABLES.

THESE cables are made from double-coated rubber wire, taped. After standing, the cable is double-taped and covered with tarred jute, over which is placed a braid of heavy cotton saturated with Weatherproof compound. This outside covering protects the rubber from the action of the air and from mechanical injury. The separate wires are tested in water, and no wire is used which will not fully meet a water test. The result is a cable which will work under water as well as on a pole line, if there is no danger of mechanical injury. The ordinary size for telegraphic work is 14 B. & S., insulated to $\frac{6}{32}$. A trace wire can be placed in each layer, if desired.

The size galvanized strand to support these cables may be found from the table page 39. Suppose the span is 130 feet and a 10-conductor 14 B. & S. G. Aerial cable is used, then from these tables it is seen a $\frac{1}{4}$-inch ordinary galvanized strand will support a cable weighing 423 pounds per 1 000 feet, with a 130-foot span.

### Specifications for 14 B. & S. Aerial Cable.

1. CONDUCTORS.

Each conductor shall be .064 inches in diameter, (14 B. & S. G.,) and have a conductivity of 98 per cent. of that of pure copper.

2. CORE.

The conductors shall be insulated to $\frac{6}{32}$ with rubber and tape, and formed into a core arranged in reverse layers.

3. PROTECTIVE COVERING.

The core shall be covered with two wraps of friction tape and one wrap of tarred jute. Over this there shall be a braid saturated with Weatherproof compound.

4. INSULATION RESISTANCE.

Each wire shall show an insulation resistance of not less than 300 megohms per mile, at 60° F., after being immersed in water 24 hours. This test shall be made on the core after all the conductors are laid up, but before the outside coverings are put on.

5. CONDUCTOR RESISTANCE.

Each conductor shall have a resistance of not more than 28 International ohms, at 60° F., for each mile of cable.

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## AERIAL CABLES.

### Rubber insulation.

| Number conductors. | 14 B. & S. G. Insulated to 4/32. | | 16 B. & S. G. Insulated to 4/32. | | 18 B. & S. G. Insulated to 4/32. | |
|---|---|---|---|---|---|---|
| | Outside diameters. Inches. | Weights, 1 000 feet. | Outside diameters. Inches. | Weights, 1 000 feet. | Outside diameters. Inches. | Weights, 1 000 feet. |
| 2 | 3/8 | 102 | 3/8 | 92 | 3/8 | 82 |
| 3 | 1/2 | 149 | 7/16 | 126 | 11/32 | 104 |
| 4 | 9/16 | 183 | 1/2 | 155 | 7/16 | 127 |
| 5 | 11/16 | 226 | 5/8 | 198 | 1/2 | 151 |
| 6 | 3/4 | 260 | 11/16 | 222 | 9/16 | 175 |
| 7 | 13/16 | 297 | 3/4 | 251 | 5/8 | 200 |
| 10 | 15/16 | 401 | 7/8 | 335 | 11/16 | 256 |
| 12 | 1 | 465 | 15/16 | 393 | 3/4 | 296 |
| 15 | 1 1/8 | 563 | 1 | 468 | 13/16 | 355 |
| 18 | 1 3/16 | 651 | 1 1/16 | 541 | 7/8 | 413 |
| 20 | 1 1/4 | 714 | 1 1/8 | 593 | 29/32 | 452 |
| 25 | 1 3/8 | 863 | 1 3/16 | 708 | 15/16 | 541 |
| 30 | 1 7/16 | 1 008 | 1 1/4 | 824 | 1 | 633 |
| 35 | 1 1/2 | 1 147 | 1 5/16 | 938 | 1 1/16 | 723 |
| 40 | 1 9/16 | 1 268 | 1 3/8 | 1 058 | 1 1/8 | 818 |
| 45 | 1 5/8 | 1 431 | 1 1/2 | 1 182 | 1 3/16 | 903 |
| 50 | 1 3/4 | 1 577 | 1 5/8 | 1 311 | 1 1/4 | 994 |

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## SUBMARINE CABLES.

| Number conductors. | Outside diameters. | Armor wires. | | Total weights. Pounds. | |
|---|---|---|---|---|---|
| | | Number of wires. | Numbers, B. W. G. | 1 000 feet. | Mile. |
| 1 | $\frac{7}{8}$ | 12 | 8 | 1 250 | 6 600 |
| 2 | 1 | 15 | 8 | 1 722 | 9 092 |
| 3 | $1\frac{1}{8}$ | 14 | 6 | 2 368 | 12 477 |
| 4 | $1\frac{1}{16}$ | 16 | 6 | 2 794 | 14 752 |
| 5 | $1\frac{1}{16}$ | 16 | 6 | 2 968 | 15 671 |
| 6 | $1\frac{1}{2}$ | 16 | 4 | 3 822 | 20 180 |
| 7 | $1\frac{1}{2}$ | 16 | 4 | 3 972 | 20 972 |
| 10 | $1\frac{7}{8}$ | 18 | 3 | 5 404 | 28 533 |

The core consists of $7 \times 22$ B. & S. tinned copper wires, insulated with rubber to $\frac{8}{32}$ of an inch, laid up with proper jute bedding.

We are prepared to furnish telegraph cables with gutta-percha insulation. This is the best insulation for submarine work, and its reliability and durability more than make up the difference in cost between it and any other insulation.

We are prepared to furnish submarine cables of any description for use in electric lighting and street railway work.

No list of these cables can be made, owing to the varying conditions to be met.

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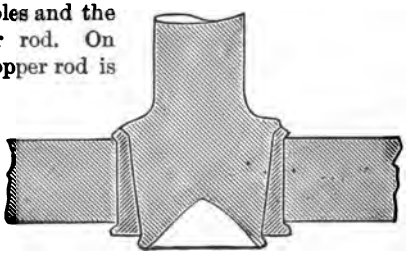
## THE COLUMBIA RAIL-BOND.

THE COLUMBIA BOND consists of three parts, two copper thimbles and the connecting copper rod. On each end of this copper rod is a truncated cone-head with a fillet at the base. The inside of the thimble is tapered to fit the head on the bond, while the outside is slightly tapered in the opposite way.



In applying the bond, the cone-shaped heads are placed in the holes in the rail from one side and the thimbles are slipped over them from the other.

A portable hand-press is then applied, and the wedge-shaped head of the bond is forced into the thimble so that it is not possible to see the line separating the thimble and the head in a cross-section of the two.

The end of the head of the bond is expanded by a center-punch, held in position in the press.

When installed, owing to the pressure exerted between the head and the thimble, and also to the fact that they are of the same kind of metal, the two become one, both electrically and mechanically.

The contact of rail and bond is made by a wedge expanding the thimble against the hole in the rail, and, as the bond is wedged both ways, it cannot get loose.

For a 0 000 B. & S. G. or 000 B. & S. G. bond, the holes in the rail should be $\frac{1}{4}$-inch, and for a 00 B. & S. G. or a 0 B. & S. G. bond, $\frac{5}{8}$-inch.

The total length of a bond is $3\frac{1}{2}$ inches more than the distance from center to center of holes in rails. The total length of a bond should be 8 inches more than that of the splice plate.

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Wire in electrical construction.
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